Corrosion

Official Publication
NATIONAL ASSOCIATION OF CORROSION ENGINEERS

MARCH 1949 No. 3

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ANNUALLY

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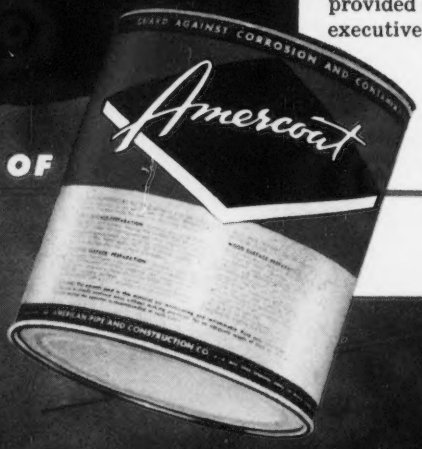

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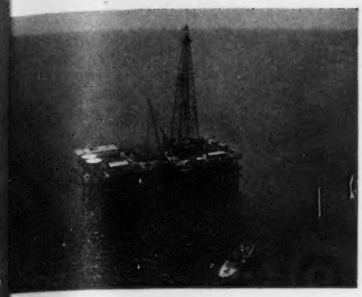

COVER PHOTOGRAPH—Humble Oil & Refining Company's rig off Grand Isle, Louisiana, is an example of the type of structure particularly subjected to corrosion damage from a marine environment. More details about this rig will be found on Page 13 in the news section.

☆

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Entered as second class matter October 31, 1946, at the Post Office at Houston, Texas, under the act of March 3, 1879.

Corrosion is Indexed Regularly by Engineering Index.

Corrosion

devoted entirely to

CORROSION
Research and Control

Published monthly as its official journal, by the National Association of Corrosion Engineers, Inc., at Houston, Texas, U. S. A., to provide a permanent record of progress in the control of corrosion as described in papers prepared for the Association and from other sources.

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A LAMB AT HOME, BUT A WOLF ABROAD!

A QUIET HUSBAND, who always acts like a lamb around the house, sometimes surprises his wife by coming home with a black eye. In the course of time it slowly dawns on this good woman that her well-trained mate may not be nearly so docile when he's away from home. And sooner or later the truth comes out. Her lamb at home is a wolf abroad!

Now corrosion often behaves like that too. There are many cases where laboratory tests, made at home, do not accurately reveal what the metal samples will do when they get out in the plant. This is not to disparage the real and important value of laboratory tests, but it means that a genuine effort must be made to see that such tests are conducted under conditions that come as close as possible to the conditions of the proposed use.

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In addition to the three major factors that enter into any corrosion phenomenon — temperature, solution velocity, and oxidizing capacity — there are a number of other factors to consider. Among them are the effect of hot or cold walls, changes in solution composition during use, unsuspected constituents and critical concentrations, water-line effects, vacuum and pressure, galvanic effects, concentration cells, and quite a few others that can cause trouble.

Frequently it is not possible to duplicate them all in the laboratory. It then becomes good policy to run plant tests, where the specimens and the way they are exposed approach as closely as possible to the metal versus solution relationship that will exist in practice.

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In cases where the spool-type holder cannot be used, holders of other design are provided. One such device, developed for use in pipe lines, is illustrated below, and still others are available for more specialized uses.

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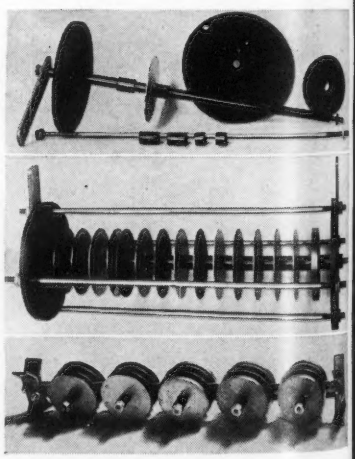

(*a*)

(*b*)

(*c*)

Spool-type specimen holder — a most useful device for plant testing. Rods, nuts and brackets are made of Monel or stainless steel. Tubes, spacers and end discs are made of bakelite, porcelain or other insulating materials. (a and b)

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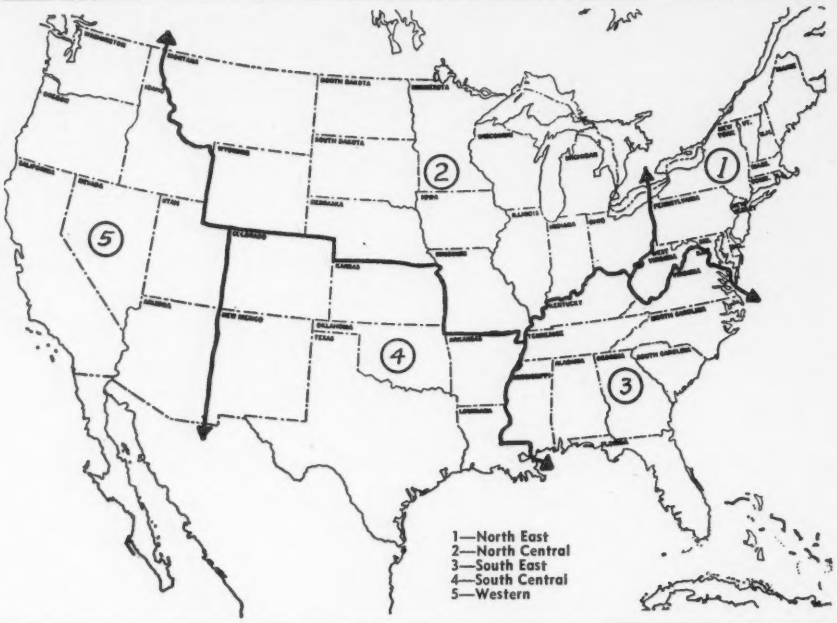

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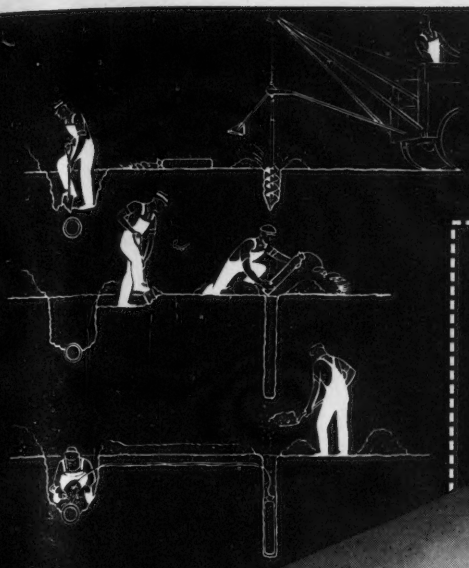

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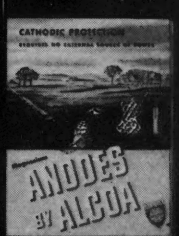

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A Message from Your Officers

This Month's Contributor

MAYNARD H. JACKSON

General Chairman, 1949 Conference and Exhibition

THE splendid work and cooperation of many committees has made it safe to predict now the 1949 Conference and Exhibition is going to be the best and finest held by the National Association of Corrosion Engineers.

All eleven symposia have papers scheduled which promise to provide a program varied, complete and interesting to those attending the conference. Significant in the technical program are the Pulp and Paper Symposium, an addition to last year's schedule; a paper on the "Corrosion Characteristics of Titanium," and the attention in the Salt Water Corrosion Symposium to the problems of those conducting operations in marine environments. While this topic is pointedly of interest to those operating plants in or near the oceans, it also holds much of value to others whose plants and equipment are intermittently exposed to salt atmosphere.

The exhibition will be composed of displays of the products and services of 55 manufacturers as well as booths for the National Bureau of Standards and the National Association of Corrosion Engineers. The North and South Halls, as well as the third and fourth floor foyers of the Netherland Plaza Hotel in Cincinnati will be filled with displays. There are 75 booths in all.

The Netherland Plaza is well laid out for a conference and exhibition of the size to be given by NACE.

Products exhibited are the latest known materials and means to be used in the mitigation of corrosion. That the exhibit space was taken better than five months ahead of the conference indicates the manufacturers' desire to support the National Association of Corrosion Engineers, and their interest in its activities. Each exhibitor will have a qualified representative present at his booth to discuss the merits of the company's products and correct methods for its effective use. This opportunity to find in one place the latest materials and information comes but once a year and this alone is sufficient reason, aside from many other valuable aspects of the conference, for many to attend.

The fact the conference is being held wholly under one roof and that other hotels are within a few blocks is another factor are added conveniences to those attending. Numerous social events have been arranged for members and their families.

This brief account of preparations for those attending tells only a part of the conference's value and interest. The "Billion dollar" annual loss due to corrosion warrants the attendance of all corrosion engineers and will have the attention of responsible management as well. This large unnecessary loss can be prevented to a great extent by the cooperation of management with engineers. This Conference and Exhibition provides the means for all to meet and to cooperate in corrosion prevention and mitigation.

Those who have been present at former NACE conferences know the time will be well spent; those who have not attended previously will be amazed at the information available to them. Members of the various committees responsible for arrangements have no reluctance in urging everyone to be present.

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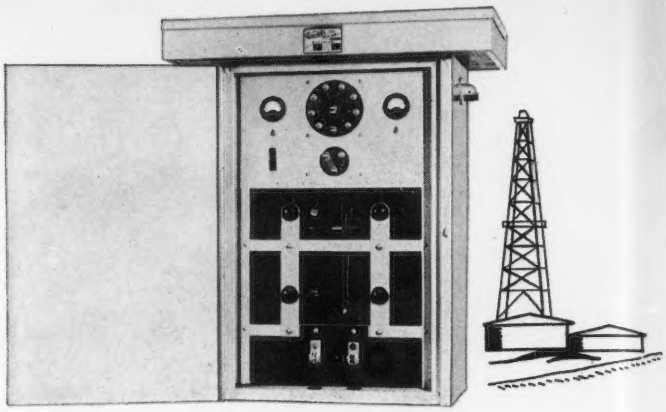

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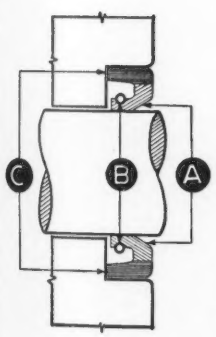

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THE NATIONAL ASSOCIATION OF CORROSION ENGINEERS

is a non-profit, scientific and research association of individuals and companies concerned with corrosion or interested in it, whose objects are:

(a) to promote scientific research in determining the causes of corrosion and methods of its control with respect to theory and practice.

(b) to provide a means of exchange of knowledge and ideas among those individuals actively engaged in the control of corrosion.

(c) to promote methods of control of corrosion.

(d) to promote standardization of terminology, methods, equipment and design in the development of methods of corrosion control.

(e) to foster cooperation between individual owners of metallic structures in the solution of their joint corrosion problems.

It is an incorporated association without capital stock, chartered under the laws of Texas. Its affairs are governed by a Board of Directors, elected by the general membership. Officers are nominated by (1) the Board of Directors, or (2) a quorum of at least 25 members, and elected by the membership.

Inquiries regarding membership, and all general correspondence should be directed to the Executive Secretary at the administrative headquarters of the National Association of Corrosion Engineers at 905 Southern Standard Building, 711 Main Street, Houston 2, Texas.

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Unusual Corrosion in High Pressure Boilers*

By S. T. POWELL and L. G. VON LOSSBERG

INTRODUCTION

The objectives of this article are:

a) To describe adequately and characterize the corrosion-embrittlement of failures;

b) Point out that corrosion-embrittlement can occur under a limited variety of operating conditions;

c) Outline possible explanations for the corrosion-embrittlement attack;

d) Indicate that caustic embrittlement can take place in welded drum boilers designed to operate at, or above, 400 psi.

e) Present exhibits to show examples of the various types of intercrystalline cracking resulting from high temperature creep, caustic embrittlement and hydrogen embrittlement;

f) Indicate the mechanics of the several types of corrosion discussed and illustrate the unusual conditions under which they can take place.

It is the author's opinion the examples cited will arouse sufficient interest to further the study of the types of corrosion and the conditions under which they take place.

THE INSTALLATION of many high-pressure boilers in recent years has introduced operating problems which were not encountered in the generation of steam at low pressures. These developments have made it imperative to provide feedwater of the highest quality and to insure meticulous care in the design and subsequent control of steam generating equipment. Numerous high-pressure boilers have been operated with little or no difficulties from scale or corrosion. In some instances, however, severe corrosion has occurred, either because of lack of proper feedwater conditioning or certain deficiencies in the design or operation of the boilers. In a few cases of serious boiler tube trouble, it has been very difficult to develop a clear-cut analysis of the attack on the metal, and to devise dependable corrective treatment.

It is not the purpose of this article to discuss boiler tube corrosion or failures which have occurred primarily because of improper treatment of the feedwater and boiler water, but to present certain unusual conditions which have, to some extent, been experienced in isolated cases but have not received widespread publicity.[1, 2, 3]

Protective Film of Iron Oxide

Experience has demonstrated that during early periods of operation of new boilers, the internal surfaces become coated with a protective film of dense adherent black iron oxide which forms under normal or desirable operating conditions. Usually, the film has a thickness of three-thousandths of an inch[4] and it remains intact without appreciable change in thickness unless damaged by physical change, chemical or electrochemical action, or a combination of these factors. When the film is broken or penetrated, the underlying surfaces may be corroded by the boiler water or steam. If the protective film is not healed, the corrosion continues at an accelerated rate.[5]

The mechanism involved in damaging the protective film and the subsequent corrosion which occurs is complex and not fully understood under all conditions. In many instances, severe corrosion has been

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★A paper presented at the NACE Conference, April 5-8, 1948, at St. Louis, Mo.

associated with the excessive formation of black, iron oxide, with or without the presence of metallic copper. In some cases, the oxide has been formed by direct attack on the metal accelerated by film boiling, while in other cases the presence of the iron oxide deposits has resulted from corrosion products brought into the boiler with the feedwater and precipitated within the tubes, forming an adherent, heat-resisting, insulating material, with an effect similar to that resulting from the presence of scale. The amount of these deposits has been insufficient, in some outstanding instances, to cause appreciable over-heating. However, rapid corrosion has occurred beneath the deposit resulting in loss of metal at the corroded areas; this action has been accompanied by embrittlement of the steel.

"Corrosion-Embrittlement"

Boiler tube failures of the type where corrosion of the metal is experienced beneath an adherent formation of black, magnetic iron oxide, accompanied by embrittlement of the adjacent steel have been designated by the authors as "Corrosion-Embrittlement." Although this term may not be entirely accurate from a metallurgical point of view, it is quite descriptive of the conditions found. The actual cases of such failures are described in the following sections.

Case One

The boilers in the plant in question are operated at 1300 psig and supplied with a high percent treated make-up water. Secondary chemical treatment of the concentrated boiler water salines is provided to adjust the pH to approximately 11.0. Excess phosphates usually are maintained in sufficient amounts to inhibit scale formation; sodium sulphite is applied to the water, but at times adequate excesses have not been maintained to insure complete removal of oxygen. Likewise, the deaerating heater has not functioned effectively under all load conditions, and some dissolved oxygen has entered the system.

Corrosion experienced as a result of the presence of oxygen occurred on some surfaces of the boiler in the form of pitting. However, the most severe attack was due not to oxygen but to other causes. Feedwater at times contained an unusually heavy concentration of ammonia, and this condition, in the presence of oxygen in the feedwater, resulted in the pick-up of fairly large amounts of copper from the heat exchange equipment. The copper was deposited in the boilers in appreciable quantities as metallic copper. It was identified both in the boiler sludges and as an adherent layer plated out on the drums and tubes. In some parts of the boilers the copper was deposited in a spongy mass, while in other instances it was laid down in sheets. Corroded areas were found adjacent to most of these deposits of spongy copper. Damaged tube sections showing the characteristic corrosion-embrittlement attack were found under layers of dense magnetic iron oxide, and considerable metallic copper was mixed with the adherent oxide. It is the authors' opinion the copper present was not the primary cause of the attack on the tubes, but accelerated the action once the corrosion started. Figures 1 and 2 reveal the nature of the attack, which was characterized by hydrogen embrittlement of the tube in the area located directly beneath the black iron oxide formations.

Figure 1—A section of corroded tube.

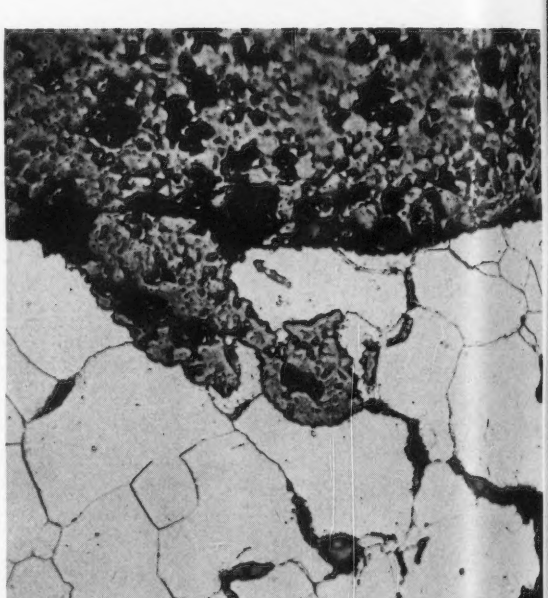


Figure 2—Photomicrograph of damaged tube metal. Note large intercrystalline crack starting from inside surface, numerous smaller intercrystalline cracks and complete decarburization. Sample of damaged tube was removed from section shown in Figure 1, polished, etched and photographed at X 100 magnification.

Case Two

A similar type of attack occurred in several other

high-pressure units which were investigated by the authors. In this plant less than 1 percent of evaporated make-up water is used. Most of the feedwater is a high quality of condensate returns. The deaeration of the feedwater has not been complete at all times, and no effort has been made to condition the concentrated boiler water; however, very little oxygen pitting in the drums or tubes has occurred. In certain areas of the boilers adherent deposits of black iron oxide were formed on the tubes and serious corrosion occurred beneath these deposits. Plated-out copper was absent. The attack was similar to that described above, viz., corrosion and embrittlement of the steel. Sufficient over-heating of the tubes to damage the metal did not develop but the steel became so highly embrittled that a section of tube walls was blown out of the elements. There was no serious deformation in the cross-section of the damaged tubes, such as occurs when over-heating as a result of the formation of deposits is the cause of failure. Furthermore, the carbides were only slightly spheroidized, which would indicate temperatures imposed on the metal were below 900° F to 1000° F, a range of temperature associated with spheroidization.

The mechanism by which this type of corrosion-embrittlement develops is not too clearly defined or understood and may depend on a number of factors. It could be explained by excessive heat or sluggish circulation resulting in metal temperature insufficient to over-heat the metal but high enough to cause film-boiling. When this condition is experienced, water vapor dissociates and the metal combines with the oxygen; magnetic oxide is formed in *situ*, with a release of nascent hydrogen. As the attack proceeds, the wall of the tube is wasted away, resulting in thinning of the cross-section. The hydrogen formed then penetrates the steel along crystallographic planes or grain boundaries, and reacts chemically with oxides, nitrides and carbides to form gaseous products within the metal. As a result of such action, tremendous pressures are created which are sufficient to rupture the grains. If the action proceeds sufficiently, the weakened and embrittled sections completely fail; and because of high operating pressures of the boilers, these sections may be blown out of the tube walls by the internal steam and water pressure. Figure 3 is a typical example of the embrittled area of tubes so attacked.

In the failures described, free oxygen was present. However, the same type of attack has been noted in the absence of dissolved oxygen.

In every instance where this type of corrosion-embrittlement has been experienced, it has been associated with heavy deposits of dense magnetic iron oxide layers on the inside of the tube at the point of attack. As earlier stated, in some of the cases copper also has been present, but failures of this type have likewise occurred in tubes where copper was absent, or only present in minor amounts in the form of black oxide. It is indicated then the mechanism can and does proceed in the absence of copper, but it is conceivable that copper, when well bonded to the metal, has accelerated the rate of corrosion and hydrogen embrittlement.

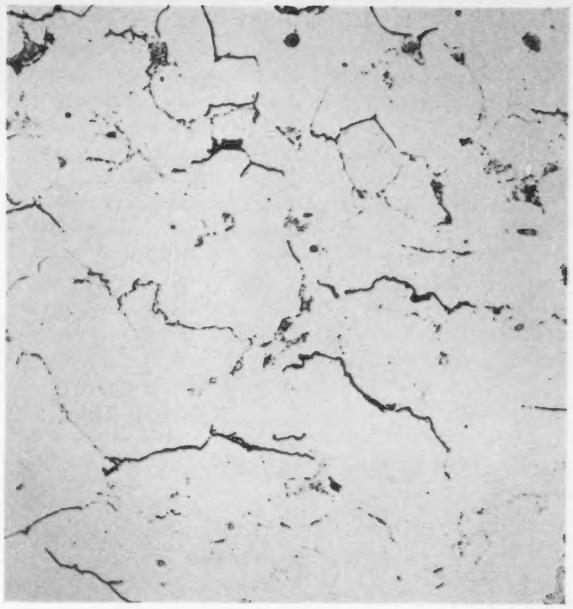


Figure 3—Micrograph of embrittled specimen from damaged water-well tube. Magnification X 500.

It is particularly interesting to note that in the corrosion-embrittlement failures investigated, overheating of the metal has not occurred or at least has not been sufficiently severe to produce failure from this cause alone.

In some boiler failures examined there was evidence to indicate much of the black oxide in the boilers was not caused by film-boiling or oxygen corrosion that took place within the boiler itself. However, the presence of the oxide was traced to products of corrosion carried into the boiler by feedwater. It appears the iron oxide ultimately baked on the internal surfaces. Oxygen corrosion resulting from dissolved oxygen in the feedwater naturally would contribute to the volume of iron oxide present.

Where this leveling of oxide to the surface was experienced, corrosion proceeded beneath the oxide formation, resulting in the same type of attack, viz., corrosion-embrittlement such as took place in boilers where film-boiling probably occurred.

It seems that sludge-like magnetic oxides, when allowed to accumulate, compact and adhere to the protective oxide films, can bring about this attack. A logical explanation of this type of failure fits in with the diffusion theory outlined by Richard C. Corey.[4, 5]

Once this bonded condition has been established the protective film is penetrated and although the deposit is hard and dense it is not homogeneous and, therefore, no longer protective to the unattacked steel. As a result, contact between metal and the steam or water could occur beneath the black iron oxide formation. The rate of attack would change from a parabolic function (characteristic of protective film) to a linear function when plotted against time. In other words, the protective film would be

destroyed substantially and the corrosion would proceed rapidly. This theory seems to be a reasonable one and readily explains the cause of the tube losses which have occurred by thinning of the tubes due to corrosion and simultaneous embrittlement from the hydrogen released when mild over-heating was not in evidence.

Corrective measures have been effected by completely removing dissolved oxygen and limiting the volume of copper and iron oxides permitted to form and accumulate in the boilers. In a few cases, redesign of the boiler itself was necessary to improve circulation and eliminate mild over-heating of the metal. Water conditioning, both internal and external, serves to eliminate dissolved oxygen and correct the characteristics of the feedwater and boiler water to prevent corrosion, minimize deposits and maintain a fluid sludge containing a limited quantity of iron oxide.

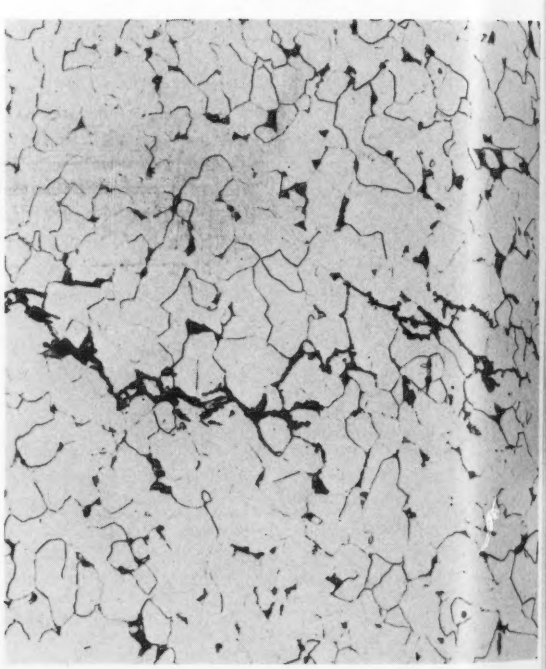
Caustic Embrittlement of Boiler Tubes at the Rolled Ends

The cracking of drums at riveted seams and the failures of tube ends at rolled joints have been recognized for more than thirty years and wide publicity has been given to such attack.[6] It is, therefore, unnecessary to discuss or describe this form of corrosion herein. With the advent of boilers constructed with welded drums, failure of drums because of caustic attack has been completely controlled, further, improvement and skill in the fabrication of boilers has practically eliminated caustic embrittlement of tube ends at rolled-in sections. This condition has been recognized by the Boiler Code Committee of the American Society of Mechanical Engineers.

An analysis of a large mass of data on boiler operation has revealed no embrittlement in boilers designed to operate at or above 400 pounds with welded, forged or exclusively internally caulked riveted drums. It is apparent, however, that caustic embrittlement can occur in any boiler where there are seams in which high concentrations of caustic can develop and where the metal is strained, a condition which can occur at rolled-in tube ends. It is for this reason that such a case investigated by the authors is presented.

Figure 4—Appearance of typical crack at rolled-in tube end.

No. 5212, X 500



No. 5216, X 200

Figure 5—Typical photomicrographs showing embrittlement cracks at surface of damaged rolled joint shown in Figure 4.

Case Three

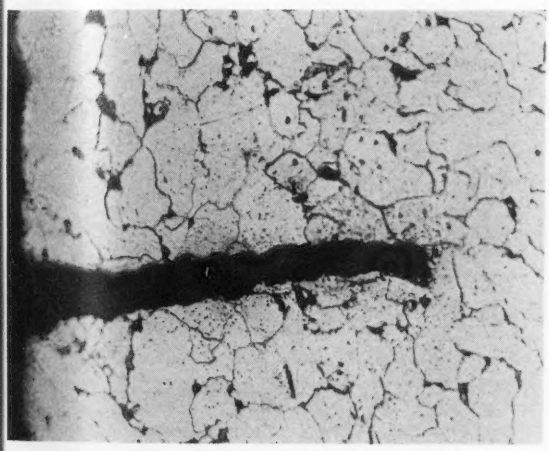
The boiler drum in question was of welded construction and designed to operate at 400 pounds pressure. The feedwater was of an embrittling type and the conditions were such that the salts could concentrate in leaky seams at the point where the tubes were rolled into the drum. Shortly after the boiler was put into operation leaks developed at the rolled-in section of the tube ends and leaking could not be

stopped by re-rolling. The tubes were removed and a metallurgical examination of the rolled-in sections showed the metal in these areas to be definitely embrittled, characteristic of caustic embrittlement failure. Samples were examined by two different metallurgists, both of whom reported the same findings.

The embrittlement of these tube-ends was so severe the entire boiler had to be re-tubed. It is of interest to note that the drums were in no way attacked and the failure was limited entirely to the tube joints. This experience indicates the need for extreme care in rolling tubes to avoid seams in which caustic solution can concentrate and joints which can "work," because when these conditions are set up, loss of tubes by caustic cracking is well within the range of possibility. Figure 4 shows a photograph of a typical cracked tube from the boiler in question and Figure 5 shows a photomicrograph of the embrittled metal section taken from the damaged tube end.

Failures Caused by Corrosion-Fatigue

Corrosion-fatigue failures have been investigated many times, so the mechanism by which such failures occur is fairly well known. The phenomenon has been described in detail by Dr. A. E. White and



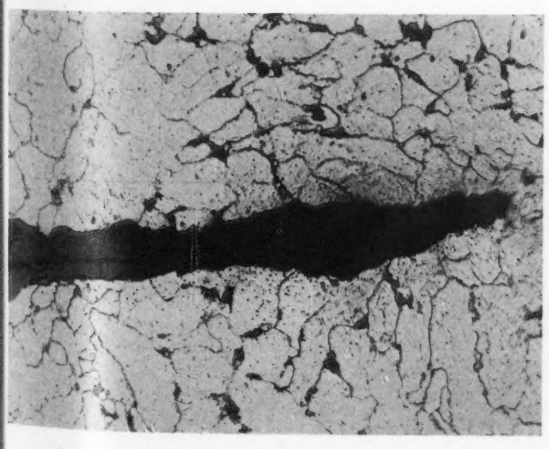


Figure 6—Top, fatigue crack near hole (X 500); bottom, corrosion-fatigue crack near hole (X 500).

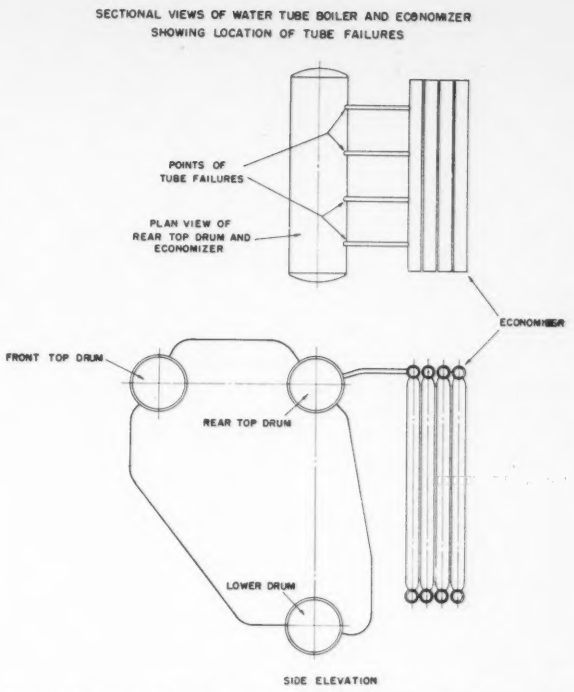

SECTIONAL VIEWS OF WATER TUBE BOILER AND ECONOMIZER SHOWING LOCATION OF TUBE FAILURES
POINTS OF TUBE FAILURES
PLAN VIEW OF REAR TOP DRUM AND ECONOMIZER
ECONOMIZER
FRONT TOP DRUM
REAR TOP DRUM
LOWER DRUM
SIDE ELEVATION

Figure 7—Sectional views of water tube boiler and economizer showing location of tube failures.

others.[2] This type of failure is caused by alternating stresses set up by vibration or other periodic mechanical or thermal changes. As is well known, cracks which occur in metal because of fatigue are predominantly transcrystalline. Failures of this type in stationary boilers are infrequent but have been noted frequently in locomotive boilers.

Where corrosion takes place in boilers accompanied by fatigue of the metal, the attack develops along a stress concentration at the surface of the metal and ultimately penetrates into the metal. A typical type of corrosion fatigue failure, which occurred in the tubes of a high-pressure boiler is shown in Figue 6. This specimen is from a rolled-in section of a feedwater tube delivering the boiler feedwater from the rear economizer header into the rear drum of a three-drum boiler. The design of this boiler and the point of attack are indicated in Figure 7. This unit was operated at a pressure of 700 psig and the temperature of the saturated steam was 503° F. The temperature of the water leaving the economizer was approximately 300° F.

The boiler design originally provided for a trough into which the feedwater discharged from the tubes and spilled into the drum by flooding this trough. However, the feedwater trough was eliminated, incidental to changes in the steam purifying accessories. The feedwater flowed intermittently into the drum, governed by the feedwater regulator, in accordance with the steam demand. This arrangement resulted in alternate discharge of the feedwater, at a temperature of 300° F, over the surface of metal which was in contact with the steam at 503° F. These widely fluctuating metal temperature conditions occurred many times each day. The straight feedwater

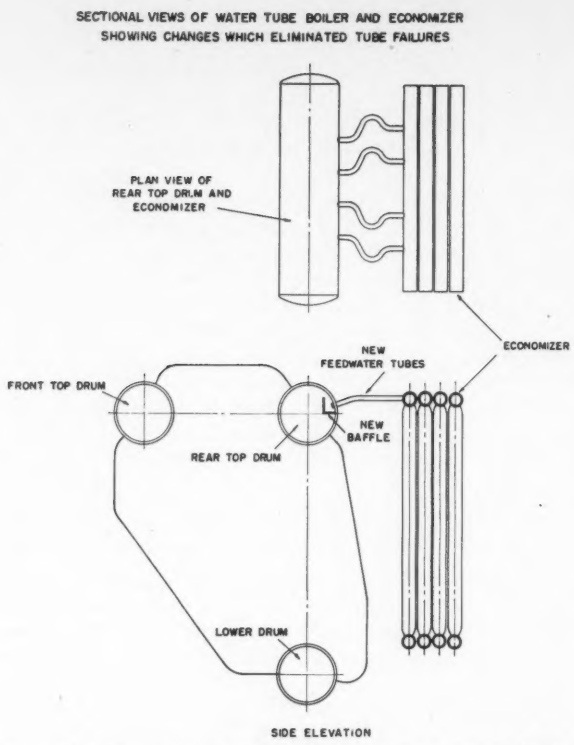


Figure 8—Sectional views of water tube boiler and economizer showing changes which eliminated tube failures.

tubes were subject to high stresses, exerted at the rolled-in section of the elements. Further, this was the point of most pronounced thermal change throughout the operation of the boiler. The combination of these conditions resulted in many failures of feedwater tubes due to corrosion-fatigue. The quality of the feedwater was not responsible for the primary or secondary attack.

The difficulty was corrected by:

a) The installation of a feedwater trough which kept the tubes flooded with feedwater at relatively uniform temperatures at all times, so the high temperature steam was not permitted to come in contact with the tube ends or rolled-in sections, and

b) The installation of S-shaped tubes to permit expansion, thereby relieving the high stresses at the ends of the tube where they were rolled into the drum. A schematic drawing showing the rearrangement of the tubes and trough subsequent to effecting corrective measures, is shown in Figure 8.

Tube Failures Due to Creep At High Temperatures

Failure resulting from high temperature creep cracks is well known and has occurred on numerous occasions, but is not common in most boiler installations. Some failures of this type were experienced in an installation recently examined by the authors. The boilers had been in service for many years and no difficulty was experienced under the normal operating conditions. Under increased demand due to wartime pressure, these boilers were greatly overloaded and shortly thereafter tube failures occurred.

It was established that at the higher ratings defective circulation developed in certain tubes, resulting in over-heating of the metal. Under such conditions, reversed circulation occurred in some of the elements. Photomicrographs (Figures 9 and 10) show the structure of the metal at points of greatest heating in the hot zones. Figure 9 reveals the carbides to be completely spheroidized, and masses of spheroids which represent the original pearlite grains tend to be elongated in the direction of the greatest stress (hoop stress). A more pronounced condition is shown in Figure 10. This grain elongation indicates plastic flow at some temperature below the re-crystallization temperature of the steel, however, considering the condition of the carbides, at a temperature high enough to accomplish spheroidization.

Figures 11 and 12 were taken about three-quarters of an inch from the point of greatest heating. Here the carbides are only partly spheroidized and the tendency to grain distortion is slight. It is evident the prevailing temperature-time relationship imposed a much less rigorous service. As indicated previously, the evidence collected in connection with the operation of the boiler shows the failures were due to excessive creep at elevated tmperature. The nature of the damage to the metal in the failed tubes indicates steam blanketing at a point of critical circulation or high heat input, or both.

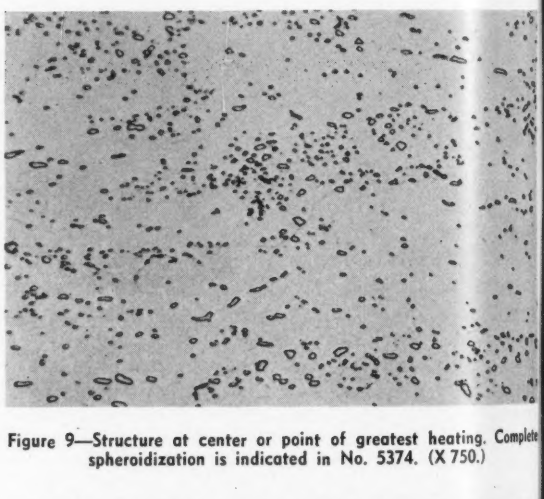


Figure 9—Structure at center or point of greatest heating. Complete spheroidization is indicated in No. 5374. (X 750.)

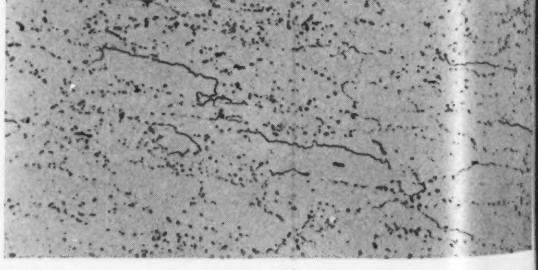


Figure 10—Structure at center or point of greatest heating. Elongated (strained) ferrite grains are seen in No. 5378. (X 200.)

A thorough study of the boiler operation indicates the failures were due to over-heating intermittently for short periods. The narrow bands affected attest to the intermittency and the short duration of the high temperature intervals.

The fact of grain elongation is perhaps the best indicator of the temperature-time relationship. It has been well established that low carbon steels or completely spheroidized steel will recrystallize in the presence of a critical strain at temperature at or below the first critical point. In view of the fact that no re-crystallization has taken place, it is evident the tube temperature during the intermittent heat periods was somewhat below 1200° F, and possibly in the range of 950 to 1100° F.

The metallurgical studies were substantiated by thermocouple measurements and other data pertaining to the plant operation. The problem with regard to creep failures in these boilers was corrected by redesigning to insure positive circulation under all operating conditions.

Procedure to Detect Corrosion Before Extensive Damage Is Experienced

A hydrogen recorded for detecting the concentration of hydrogen in the steam is an effective and positive means for detecting the rate of attack which may be proceeding within the boiler.

The Cambridge Hydrogen Recorder which is designed for measuring hydrogen in parts per billion or fractions of a part per million, has been employed by the authors and others in special studies for detecting the rate of corrosion occurring in steam generating units. The recorder is valuable because it gives a continuous record of the gas in the steam and the results can be correlated with operating conditions in the plant and with the hydrogen release for a normal well designed boiler. In one case in particular where heavy iron oxide accumulations frequently resulted from starved boiler tubes, the Cambridge Hydrogen Recorder was found to be helpful since it detected attack on the wall tubes by showing excessive hydrogen in the steam. As soon as this condition was noted, the boiler was taken out of service and the tubes were cleaned.

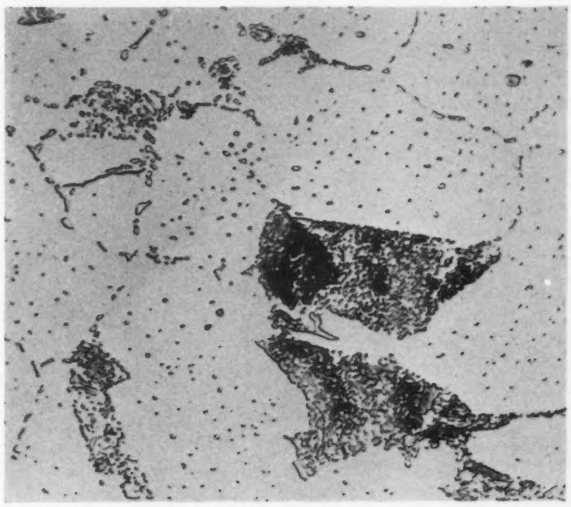
The hydrogen recorder also has proved of value in detecting over-heating of tubes resulting from steam blanketing and the corrosion-embrittlement type of attack.

For adequate evaluation of the data provided by a hydrogen recorder, it is necessary to measure, as a blank, the hydrogen in the feedwater delivered to the boiler, because it has been found that considerable dissolved hydrogen is re-circulated in the steam-water cycle.

If the sampling nozzle delivering saturated steam to the hydrogen recorder is located properly, this instrument will detect a rapid increase in the amount of hydrogen generated, whenever there is corrosive attack on the metal. When these data are correlated with operating experience, they serve as a useful guide in evaluating the nature of the attack and the extent to which the corrosion is proceeding. The sampling and recording apparatus must be operated with extreme care in order to produce a reliable record but where such information has been available, the cost of the installation has been justified.

Measurement of Thickness of Deposits

Instruments which will detect scale or deposits on tube surfaces as well as damaged tubes during boiler inspections have been developed. They have merit in some cases, since they may indicate a condition occurring in the tube and give some warning of the attack which is proceeding in areas which may not be examined visually because of their inaccessibility. The Turner Boiler Scale Tube Thickness Indicator has proved of value in this respect. The indicator works on a magnetic principle and is suitable only for measuring scale on metals that have magnetic properties. It is extremely sensitive and will indicate scale thickness in the magnitude of .001 inch. When



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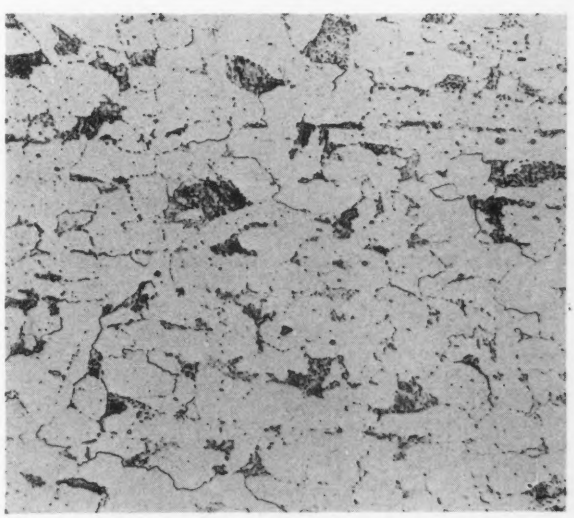

No. 5379—X 200.

Figures 11 (top) and 12 (bottom)—These micrographs show the structure ¾-inch around the tube circumference from the center of a bulge. Carbid spheroidization has only started.

the probe-head of the instrument is passed over pitted, or corroded, areas, the needle of the indicator fluctuates considerably; this can be used as a guide to detect pits. Although the black iron oxide is magnetic, its properties are sufficiently different from that of steel to make it possible to measure the thickness of this material with some accuracy.

Acid Cleaning

Where heavy accumulations of oxide are present in boilers, especially as a result of corrosion-embrittlement attack, complete removal by acid cleaning often is desirable. Such cleaning is preferred to turbining because the oxides can be removed more effectively than is possible by turbining alone. Modern high-pressure units often have many inaccessible tubes or the tube arrangement precludes removal of deposits by mechanical methods. It is for this reason that cleaning with inhibited hydrochloric acid has been found to be more satisfactory for removing the heavy, dense magnetic iron oxide scale formed over a wasted area. Although the acid does not completely dissolve the scale, it penetrates into the crevices and loosens it sufficiently so that it can be removed as a sludge when the boiler is flushed subsequent to the cleaning treatment.

The fact that the scale can be penetrated by the inhibited acid is indicative it is porous and, therefore, allows progressive attack upon the metal as described under Corrosion-Embrittlement.

Extreme care should be exercised in acid cleaning of boilers or other power plant equipment. A number of accidents have resulted from such operations when carried out by inexperienced persons, injury to the plant personnel and damage to equipment has been taking place. Operators who wish to have the boilers acidized should first secure the services of those qualified to do such work, or familiarize themselves with all the hazards involved and the precautions to be taken if they plan to do the acid cleaning themselves.[7]

Conclusions

1. Corrosion-embrittlement attack has occurred in high-pressure boilers using chemically treated or evaporated make-up.
2. Corrosion-embrittlement is characterized by the corrosion of the metal beneath a hard, dense scale of black magnetic iron oxide. Metal adjacent to the corroded area becomes brittle as a result of intercrystalline cracking caused by hydrogen. The attack may, or may not, be associated with dissolved oxygen or metallic copper. Temperatures sufficiently high to damage the metal are not characteristic of such failures.
3. The mechanism of corrosion-embrittlement can be explained as a result of sluggish circulation causing film boiling at temperature below the crystallizing point of the steel. Further, the corrosion theory advocated by Corey which accounts for damage to the protective film resulting from diffusion as excessive deposits of black, magnetic iron oxide form on the tube surfaces is an explanation more in keeping with certain observations made by the authors.
4. The formations of adherent black magnetic iron oxide beneath which the corrosion-embrittlement takes place can be removed by acid cleaning. This method has been found successful when turbining of the tubes failed to dislodge adherent iron oxide scale from the corroded areas.
5. Changes in operating conditions, such as increasing the load, can adversely affect boiler circulation in critical units causing the failure of tubes due to high temperature creep as described herein.
6. Caustic embrittlement can occur at the tube joints in welded drum boilers designed to operate at, or above, 400 psi.
7. The hydrogen recorder is favored in predicting the initiation of an attack upon the metal before appreciable damage has resulted.
8. During the inspection of a boiler, the scale measureing device described has helped in locating in tube sections which are not visible or otherwise accessible for observation patches of scale, especially the bonded black magnetic iron oxide beneath which corrosion embrittlement has occurred.

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A Cooperative Approach To Electrolysis Problems*

By **RUSSELL M. LAWALL**

THE RAPID expansion of street railways and interurban lines during the World War I era brought acute problems of stray currents in many municipalities. As early as 1917, the Omaha and Council Bluffs Electrolysis Committee was organized, for the purpose of preventing objectionable competitive drainage, and to provide for systematic electrolysis measurements. Twelve companies cooperated, and through the work of their technicians succeeded in limiting drainage to the smallest practicable amount. In 1920 similar action was taken in Milwaukee at the instigation of the Railroad Commission of Wisconsin. In 1921, J. C. McCabe, research engineer of the city of Detroit, called a meeting of representatives of sub-structure companies of Detroit, and groundwork was laid for the organization of the Detroit Electrolysis Committee which was effected the following year. In these, and similar groups organized elsewhere, it became apparent the nature of electrolysis problems demanded a cooperative, rather than an independent approach.

RUSSELL M. LAWALL

Presently an engineer with American Telephone and Telegraph Co., Detroit, Mich., and among other duties is responsible for corrosion and electrolysis protection of underground cable plant in Detroit. Earlham College, B.S., Case Institute of Technology, B.S.E.E. For 19 years actively concerned with plant maintenance work. Chairman of the Detroit Committee on Electrolysis.

Organized in 1922

The Detroit Committee on Electrolysis was organized formally in 1922 to encourage cooperative efforts in Detroit and adjacent communities toward abatement of destructive corrosion conditions caused by stray currents and local, galvanic, or chemical action. Stray currents are the result of leaks from grounded electrical distribution systems, such as direct current electric railway systems, grounded neutrals in direct current power and lighting systems, ground return of uni-directional welding systems and cathodic protection systems. When grounded returns are used to complete an electric circuit (for example, the rails in a street railway system), it is know that part of the return current strays from its intended path and finds an easier path by passing into the earth and over underground metallic structures to its electrical source. It is known also there are varying amounts of damage done to these substructures, such as pipes and cables, by stray currents passing from one structure to another.

In addition to stray current destruction, damage is also caused by conditions resulting from self-generated electric current, namely galvanic potentials set up by dissimilar metals in an electrolyte, difference of soil to structure contact, oxygen concentration, substructure make-up and other electro-chemical reactions resulting in unequal potential values on the substructure surface.

Large Investment Involved

In Detroit and surrounding communities there is a very large investment in pipes and cables installed underground which are owned and operated by municipal and private interests. The size of this investment warrants careful consideration of all corrosion hazards and the application of proper mitigative measures.

The government of this organization (Figure 1) is vested in a body called the General Committee. This committee meets at least three times a year and consists of one official representative and alternate from each member organization. These representatives usually are officials, executives or supervisors of the company each represents and are familiar with corrosion problems. It is empowered to act on all recommendations, reports and findings pertaining to corrosion, submitted it by any member. Officers of the General Committee consist of a chairman, vice chairman and secretary-treasurer. The organization includes also two standing committees—executive and technical. Subcommittees may be appointed by chairmen of committees as required.

The executive committee consists of the officers of the General Committee, two members at large and the chairman of the Technical Committee.

This committee plans and controls the general order of business for the Detroit Committee on Electrolysis.

*A paper presented at the annual meeting of NACE in St. Louis, Mo., April 5-8, 1948.

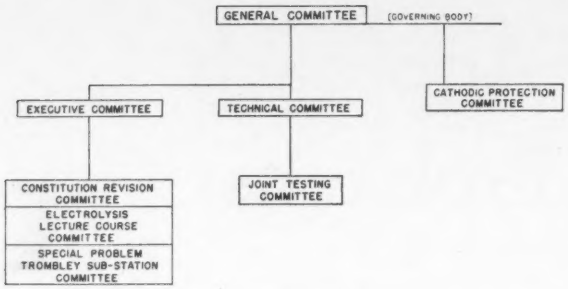

Figure 1—Organization diagram.

The Technical Committee consists of a chairman, secretary and at least five representatives from member organizations. These representatives usually are field people actively engaged in the detection, measurement and mitigation of electrolytic problems. This committee meets at least four times a year, and recommends necessary tests, devises methods and makes tests, makes analytical reports to the general committee and may call upon member organizations for assistance in the form of men and testing equipment.

Membership in the organization may be maintained by any company or municipal department which has property in Detroit and adjacent communities and is involved either in creating conditions which may cause electrolysis or possesses property which may be damaged thereby. The by-laws of the committee provide for an annual assessment of $25.00 per member company to cover operating expenses. However, during the years this committee has been functioning, the preparation and distribution of minutes of meetings and compilation of engineering data have been the only expenses incurred. These nominal clerical expenses have been borne by the various companies by which the secretaries were employed.

Lecture Series Is Given

During the last few years, it has been planned to have well-known speakers talk before the General Committee on some of the latest developments in the electrolysis field, or some associated project. In 1946, the committee sponsored a lecture series consisting of nine weekly meetings, which started February 14. For this course 95 men were enrolled, the highest weekly attendance was 73 and the lowest 26. At these meetings held at the Lawrence Institute of Technology, various functioning factors contributing to the electrolysis problem were brought to the attention of the group. Topics considered and discussed dealt with:

1. Description and details of instruments utilized by electrolysis and corrosion investigation.
2. Theory of electrolysis and corrosion action.
3. Sub-station operation.
4. Street car rail installation, bonding, electrical feed and drainage.
5. and 6. Measurements made on typical, routine inspection jobs. Methods of making connections, outline of contact points, manner of logging data and data interpretation.
7. Installation of automatic switches and resistance for cable plant protection.
8. Installation and electrolytic drainage of pipe, including pipe insulation practices. Methods of testing insulated pipe installations.
9. Cathodic protection methods used in the Detroit area. Description by Michigan Bell Telephone Company of the central stray current measurement station.

At the present time records of the various mitigative measures installed in the metropolitan area are being completely revised, and in most cases, redrawn, to show the remedial projects installed by the various member organizations. When completed, these maps will bring up to date the records of bonds, drains and cathodic protection systems maintained by the various member companies of the Detroit committee. The map of Detroit and surrounding communities is subdivided into sections similar to Figure 2, which shows part of Section 10 of the metropolitan area map. This map section is an outline of the electrolytic mitigation system for this particular area, showing only the locations of the various protective installations which are indicated by the letters A, B and C. Figures 3, 4 and 5 show details of each separate installation. For example, Figure 3 or plate 10-A shows a bond connecting the Michigan Bell Telephone cable to the Public Lighting Commission cables at Lafayette and Livernois. Figure 4 shows a joint drainage system at Fort and Ferdinand connecting the

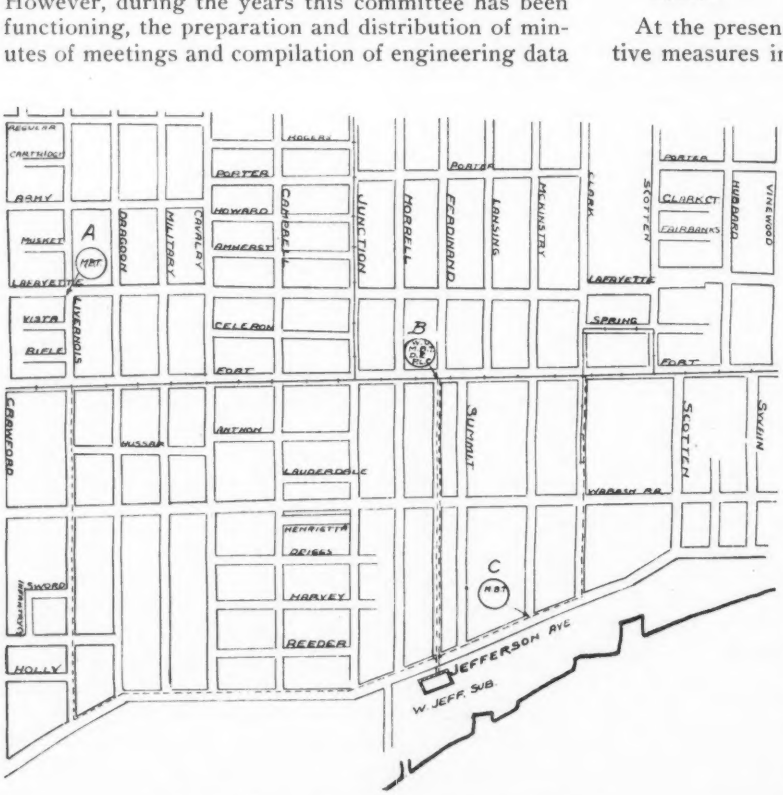

Figure 2—Part of Section 10 of metropolitan area map.

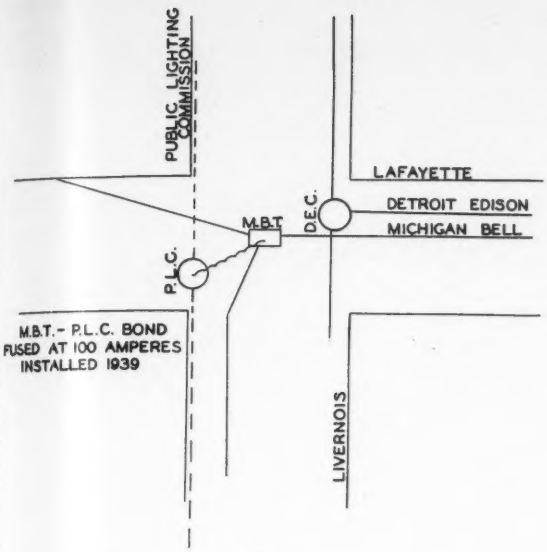

Figure 3

Detroit Edison, Public Lighting Commission, Western Union and Michigan Bell Telephone cables through an electrolysis automatic switch to a Department of Street Railway negative. Figure 5 shows a drain connection betwen the Michigan Bell Telephone cables and the Department of Street Railway negative at W. Jefferson and McKinstry. All details of size of wire, size of fuse, interconnections and type of equipment used are shown on the drawings. Figure 6 gives the key to symbols used in the over-all and section maps.

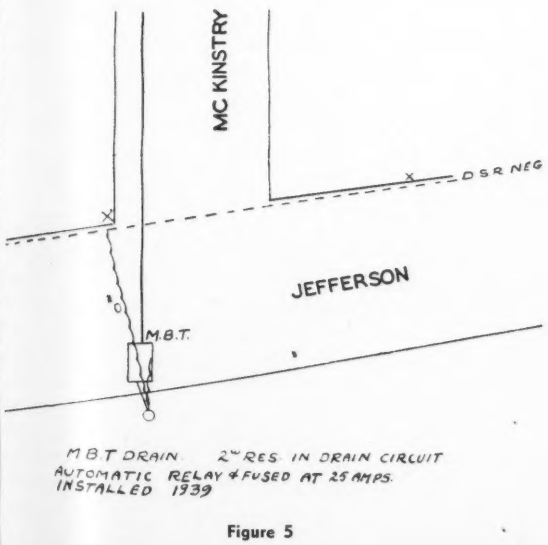

Figure 5

It is interesting to observe in looking over the history of the organization, that three different case numbering systems have been used: First, consecutive serial numbers until 1928. Second, the zone system, numbered serially in each of the 37 zones until 1943 (normally the sub-station area). Third, consecutive serial numbers with suffixes of the year inaugurated in 1943. This latter system is being used at present. Approximately 300 problems have been handled by the electrolysis committee over the past 26 years.

Case Illustrates Operation

Case Number 34-35, involving the Hart Sub-Station Area in Detroit (Figure 7) typifies the cooperative effort of committee members to assist in the mitigation of electrolysis problems.

On April 19, 1945, the Detroit Edison Company reported to the Technical Committee a cathodic cable failure at Tennessee and Jefferson Streets. In this report was included the suggestion that if the negative feeder to rail was removed at the corner of Hart, south of Kercheval, it would reduce drainage

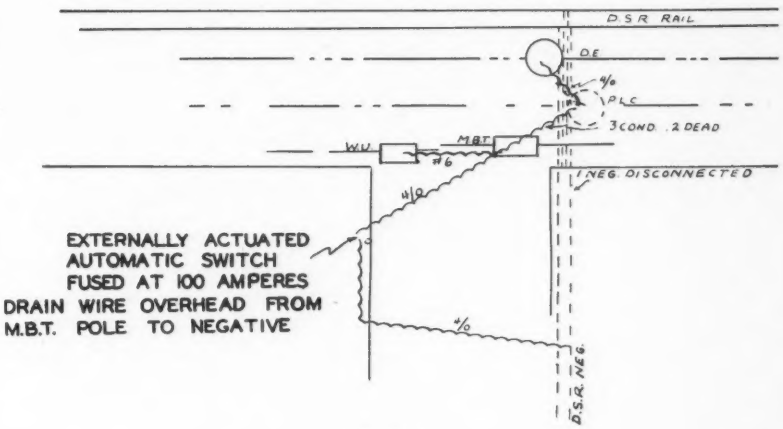

Figure 4

in the Kercheval area and increase the drainage along the Jefferson Avenue tracks. Other companies involved in this problem were the Michigan Consolidated Gas Company, Department of Water Supply, Michigan Bell Telephone Company and the Public Lighting Commission.

On June 14, 1945, in response to a request, the Detroit Street Railways agreed to open for test purposes the negative feeder on Hart south of Kercheval, for a trial period of three months (Figure 7).

On August 23, a joint survey of this area was recommended, to be made September 5, 1945. Prior to the presentation of this case to the Technical Committee, joint surveys had been made in this area, with conditions normal on April 13, and with track negative open and with track negative and utility drain open on April 12.

In the fall of 1945, tests were made in this area after rail feeder on Hart south of Kercheval was opened. It showed the amount of current drained with feeder open to be about one-half of normal. At the

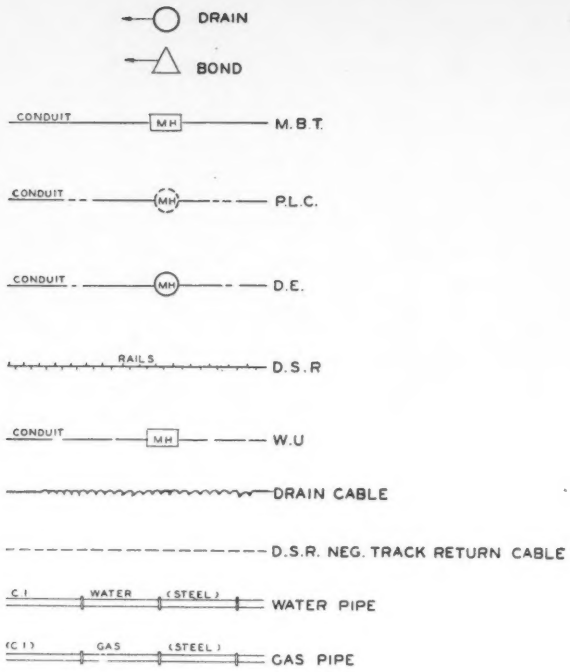

Figure 6

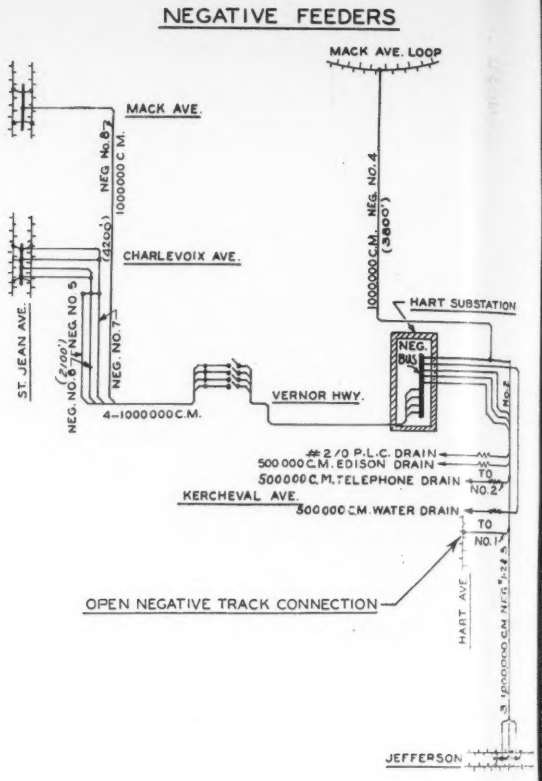

Figure 7

request of the Technical Committee, this rail feeder was opened permanently. On November 7, 1946, it was decided that the tests made on April 12, and in the fall of 1945, were conclusive enough, inasmuch as the Detroit Edison Company cables were now only about one volt negative to rail instead of the original four volts. (Complete data taken on April 12 and 13 is shown in Appendix I.)

Field data for the Technical Committee is recorded on the form shown in Figure 8.

DETROIT COMMITTEE ON ELECTROLYSIS Case No. 34-45

Location HART & KERCHEVAL

Time 2:30 P.M. Date 3/23/45

STRUCTURE POLARITY										Reading (Volts)	Anodic Structure	Cathodic Structure
Gas	M.B.T.	Fire	Police	P.L.C.	Water	Ground	D.S.R.	Edison				
					−		+			+.5V	D.S.R.	WATER
				+	−					−.2	WATER	P.L.C
		+	+		−					−.3	WATER	POLICE & FIRE
+					−					+.5	GAS	WATER

Remarks: GAS PIPE NEEDS PROTECTION Observer M. L. ENSLEY

Figure 8

Technical Committee results are forwarded to the committee members. (The present form used for these data in Case 32-45, are given in Appendix II.) Costs of the initial survey when a failure has occurred, and the final survey after the remedial measures have been put into effect, including remedial installations, are borne by the company whose plant is being protected and are not pro-rated over the membership of the committee. Expenses incurred in any rearrangement or diversion of negative feeders requested by the committee is assumed by the Department of Street Railways. When the Technical Committee is faced with a problem beyond the ordinary routine, or one involving a considerable amount of expense, the matter is referred to the Executive Committee in order to achieve an equitable solution of the problem.

In the first 15 years from 1922 to 1937, there was an average of nine members attending each Technical Committee meeting. During the same period, there was an average of 14 members attending each of the General Committee meetings. In the next eleven years, 1937-1947, inclusive, there was an average of 13 members attending each Technical Committee meeting. During the same period, there was an average of 30 members attending each General Committee meeting. The Technical Committee has maintained a somewhat uniform nucleus of representatives from the larger organizations, and hence

does not show a marked increase of attendance, as does the average for General Committee meetings. Technical Committee representatives from the smaller companies tend to withdraw from active participation in this Committee after their particular problem has been solved. On the other hand, the growth of the attendance at General Committee meetings may be due to the educational effect of the splendid talks presented by outside speakers at these meetings, plus an influx of new members from interstate pipe line organizations.

Active Future Forecast

As to the future of the Detroit Committee on Electrolysis, it can be pointed out definitely that changes are expected. However, committee members are firmly convinced they can meet changing conditions most advantageously by working together. Pooling of knowledge, equipment and personnel makes for greater efficiency for each member company. Planning tests cooperatively means that data can be secured with uniformity of conditions and a minimum of labor. Present trend of the transportation system of Greater Detroit is toward the replacement of street railways by gasoline or Diesel-powered buses. While this situation may greatly reduce the stray current, on the other hand, an electric subway system, long contemplated by the city, might introduce greater problems. Whatever the changes may be, the Detroit Committee on Electrolysis can recommend heartily the cooperative method for attacking the problems.

Appendix 1

Joint Committee Survey

(April 12, 1945)

These readings were taken with the D.S.R. Negative disconnected on Hart, south of Kercheval.

10:40 A.M. Fairview and Kercheval.
Water—Negative .7 to Negative .1 to Rail.
" —Positive .5 to Positive .6 to M.B.T.
" — " .2 to " .3 to P.L.C.
" — " .16 to " .35 to Detroit Edison.
" Gas Neutral.

11:00 A.M. St. Jean and Kercheval.
Water—Negative .015 to Negative .005 to Gas.
" — " .5 to " .8 to Rail.
" —Positive .12 to Positive .3 to Detroit Edison.
" — " .25 to " .72 to M.B.T.
" — " .35 to " .72 to P.L.C.

11:20 A.M. St. Jean and Charlevoix.
Water—Negative .35 to Positive .35 to Rail.
" —Positive .06 to Positive .22 to Detroit Edison.
" — " .06 to Gas.

11:45 A.M. Kercheval and Hart.
Water—Negative .2 to Negative 1.5 to Rail.
" —Positive .35 to Positive .55 to M.B.T.
" — " .25 to " .45 to Detroit Edison.
" —Negative .1 to Negative .25 to Gas.
" —Positive .3 to Positive .5 to Police.
" — " .35 to " .5 to P.L.C.

10:40 A.M. Tennessee and Jefferson.
M.B.T.—Negative 1.2 to Negative .4 to Rail.
Water —Positive .08 to Positive .12 to Detroit Edison.
" — " .07 to " .18 to P.L.C.
" —Negative 4.4 to " .4 to Rail.
" —Positive .18 to " .35 to M.B.T.

11:00 A.M. Hart to Jefferson.
Water—Positive .04 to Positive .22 to M.B.T.
" —Negative 2.00 to Negative .2 to Rail.
" — " .38 to " .14 to Gas.
" —Positive .08 to Positive .26 to Detroit Edison.
" — " .02 to " .15 to P.L.C.

11:00 A.M. St. Jean and Jefferson.
Water—Positive .07 to Positive .16 to P.L.C.
" — 0 to Negative .7 to Rail.
" — " .22 to Positive .56 to M.B.T.
" —Negative .07 to .36 to Detroit Edison.

These readings were taken with the D.S.R. Negative disconnected on Hart, south of Kercheval and all Utility Drains disconnected.

1.50 P.M. Fairview and Kercheval.
Water— 0 to Negative 1.0 to Rail.
" —Positive .03 to Negative .13 to M.B.T.
" — " .23 to Positive .05 to Detroit Edison.
" — 0 to Negative .001 to Gas.

2:10 P.M. St. Jean to Kercheval.
Water—Negative .1 to Negative 1.0 to Rail.
" — .08 to " .12 to Gas.
" —Positive .1 to Positive .8 to Detroit Edison.
" — " .05 to " .4 to M.B.T.
" — " .1 to " .2 to P.L.C.

2:30 P.M. St. Jean and Charlevoix.
Water—Positive .31 to Detroit Edison. Average—Positive .1.
" —Negative .005 to Positive .5 to Rail.
" — 0 to Positive .1 to Gas.

2:45 P.M. Hart to Kercheval.
Water—Negative .3 to Positive .6 to Rail.
" —Positive .25 to Negative .02 to Detroit Edison.
" — " .1 to " .02 to P.L.C.
" — " .005 to " .005 to Gas.
" —Negative .25 to 0 to M.B.T.

1.45 P.M. Tennessee and Jefferson.
Water—Negative .04 to Positive .08 to M.B.T.
" — " .10 to " .15 to P.L.C.
" — " 2.3 to " 1.2 to Rail.
" —Positive .03 to " .26 to Detroit Edison.

2:05 P.M. Hart and Jefferson.
Water—Negative .36 to Negative .03 to M.B.T.
" — " .8 to Positive .5 to Rail.
" —Positive .03 to " .25 to Detroit Edison.
" — " .04 to " .24 to P.L.C.

2:50 P.M. St. Jean and Jefferson.
Water—Positive .06 to Positive .19 to P.L.C.
" —Negative 1.2 to " .2 to Rail
" — " .28 to Negative .04 to M.B.T.
" —Positive .06 to Positive .41 to Detroit Edison.

(Sgd.) John R. Toth
Secretary Tech. Comm.

(Appendix 1 Continued on Next Page)

Appendix 2

Detroit Committee on Electrolysis, Case No. 32-45

Location—Rivard & Madison

Time—10:00 a. m.
Date—September 25, 1947

STRUCTURE POLARITY										
Gas	M.B.T.	Fire and Police	24,000 V. P.L.C.	East Water	Police Run No. 2	Weather Proof Joint Drain	West Water	Reading (Volts)	Anodic Structure	Cathodic Structure
.....	.....	.....	.....	+	.....	.....	—	. 0/—.025	West Water	East Water
+	.....	.....	.....	.....	.....	.....	—	+.01/+.028	Gas	West Water
.....	+	.....	.....	.....	.....	.....	—	—.6 /—1.0	West Water	M.B.T.
.....	.....	+	.....	.....	.....	.....	—	—.08/— .16	West Water	Police & Fire
.....	.....	.....	+	.....	.....	.....	—	—.6 /— .8	West Water	P.L.C.
.....	.....	.....	.....	.....	+	.....	—	—.14/—.20	West Water	Police
.....	.....	.....	.....	.....	.....	+	—	—2.0/—3.0	West Water	Drain
.....	.....	.....	.....	.....	.....	*+	—	+.15/+.30	Drain	West Water

Remarks: * With drain open at substation.
Stationload 1200 amps.
P.L.C. vault pumped dry.

Location—Rivard between Clinton and Macomb
Date—September 25, 1947. Time—1:30 p.m.

Notes:

1. At the joint cable drain at the alley south of Clinton, the copper and the sheath are common, thus extending the station negative to this location.
2. The weatherproof drain which lies between Rivard and Gratiot and the Mullett substation is bare in spots.
3. The Police 7 Fire cables are not bonded at the alley north of Clinton.
4. The Police and Fire drain 18 amperes to the M.B.T. cables from Macomb and Rivard.
5. Water and Gas mains are drained at Clinton and Rivard.
6. The drop over the Police drain at the alley is 0.1V.
7. Drop over Police and Fire drain, Macomb to Alley North, 0.12 to 0.17V with present drain.
8. Drop over Police and Fire Drain, Macomb to Alley North, 0.06 to 0.1V with present drain reinforced by a "0" gauge drain—7 amperes drained over the "0" gauge cable.

Observer: A. H. Cramer

Joint Committee Survey
(April 13, 1945)

10:15 A.M. Fairview and Kercheval.
Water—Positive .1 to Negative .3 to Rail. Average .1 Neg.
" — " .3 to Positive .6 to M.B.T.
" — " .15 to " .3 to Detroit Edison.
" —Gas Neutral. .15 to " .2 to P.L.C. Average .18 Pos.

10:35 A.M. St. Jean and Kercheval.
Water—Negative .15 to Negative .5 to Rail.
" — " .05 to " .1 to Gas.
" —Positive .2 to Positive .35 to P.L.C.
" — " .1 to " .45 to Detroit Edison.
" — " .3 to " .6 to M.B.T.

10:50 A.M. St. Jean and Charlevoix.
Water—Negative .1 to Positive .2 to Rail. Holds close to 0.
" —Positive .05 to " .2 to Detroit Edison.
" — " .01 to " .03 to Gas.

11:10 A.M. Hart and Kercheval.
Water—Negative .8 to Positive .3 to Rail.
" —Positive .3 to " .4 to M.B.T.
" — " .15 to " .42 to Detroit Edison.
" — " .08 to " .2 to Gas.
" — " .2 to " .5 to P.L.C.

10:15 A.M. Jefferson-Tennessee.
Water—Positive .12 to Positive .38 to Detroit Edison.
" —Negative .08 to " .18 to P.L.C.
" — " 3.1 to " .3 to Rail.
" —Positive .12 to " .28 to M.B.T.

10:40 A.M. Hart and Jefferson.
Water— 0 to Positive .12 to M.B.T.
" —Negative 1.2 to Negative .1 to Rail.
" — " .2 to " .07 to Gas.
" —Positive .02 to Positive .21 to Detroit Edison.
" — " .04 to " .14 to P.L.C.

10:55 A.M. St. Jean and Jefferson.
Water—Positive .05 to Positive .11 to P.L.C.
" — " .12 to " .34 to M.B.T.
" —Negative 1.2 to Negative .3 to Rail.
" —Positive .04 to Positive .28 to Detroit Edison.

These readings were taken under normal conditions.

DISCUSSION

By Irwin C. Dietze *

In Los Angeles, California, we have a group known as the "Electrolysis Committee of Southern California," which meets bi-monthly in the Water and Power Building of the Department of Water and Power. Our membership of 28 consists of one or more representatives from the local water, telephone, gas, telegraph, and electric companies, both electric railway systems and all the oil companies in this section.

At our meetings we have a report from each of the two electric transit lines on additions and changes to the existing electric trolley system and what effect it will have on the utilities operating in the area affected. Abandonment of old rail systems, which is taking place all over the country, oftentimes presents some special problems. By knowing some time in advance what changes are to be made we can make our plans accordingly. Arrangements are made at these meetings for cooperative tests on drainage bonds to the railway substation when changes are made or found in the track system return circuits.

In and around Southern California a great many cathodic protection systems are being installed for the protection of water, gas, oil and cable systems. These installations are discussed at these meetings so that those concerned can make plans for their operation. After these installations are made a notice is sent to each member of the committee advising them of the size and location of the anodes, rectifiers and the system protected. The notices are sent by the utility making the installation. With this information each utility can make tests on its own system to see if it is affected.

Discussion at these meetings often brings forth valuable experiences and installations that some of the members are working on.

Attendance is purely voluntary and the cooperation between the utilities and the electric transit lines is excellent.

This committee was organized about ten years ago and has met regularly except during the war period.

* Electrolysis Engineer, Department of Water and Power of the City of Los Angeles.

DISCUSSION

By Frank B. Fry *

Mr. Lawall's paper is very interesting and brings out this very important fact: If we are to accomplish control of corrosion and stray current electrolysis, particularly in urban areas where the network of underground structures is very complex, we should continue to organize and operate more committees such as those operating in over 50 cities. The best and most effective method of attack is by cooperating together, helping each other.

Our corrosion problems are beginning to take on different characteristics because transit companies are in the throes of converting their street car systems to trolley bus or Diesel powered bus lines. With this conversion comes the loss of free cathodic protective current, and the resultant problem of providing our own protection. Under such conditions a corrosion committee can be a very useful tool.

* Public Service Company of Colorado.

DISCUSSION

By W. Beck *

Mr. Lawall's interesting paper makes clear it is extremely advantageous to mitigate electrolytic corrosion troubles by cooperation in the form of local or *national* committees. Perhaps it will be of interest to direct your attention to the fact that there are also *international* committees.

Three leading institutions—the International Advisory Committee for long distance cable lines, the International Conference for the Large High Voltage Lines and the International Railway Association—established in 1929 a special commission. This is the International Joint Commission (C.M.I.) for the study of methods to protect metallic installations against subsoil corrosion. Delegates of government institutions of many nations have chairs in this commission, but there are also technical deputies from various national associations of gas, water and electrical engineers. There is a meeting every three years, usually in Paris. Reports (not papers) are submitted and corrosion experiences are thoroughly discussed.

As a member of the International Advisory Com-

* Corrosion Research Laboratory, Department of Metallurgical Engineering, Lehigh University, Bethlehem, Pa.

mittee (C.C.I.F.) the American Telephone and Telegraph Company is automatically a member of the C.M.I., but developed only a limited activity.** I, myself, worked with the C.M.I. many years and am now a corresponding member. I am convinced I speak in the interest of the corrosion engineers in this country, if I propose that the NACE become a member of the C.M.I. In such a way we will be able to profit from the broad corrosion experiences of the C.M.I., and abstracts of the international corrosion reports could be published in the English language in CORROSION. The original reports are written in French, and this is also the official language of the international discussions.

** Report of H. S. Warren of the American Telephone and Telegraph Company, submitted to the C.C.I.F. in 1929. Report of W. C. White of the same company submitted to the C.C.I.F. in 1931.

TECHNICAL PAPERS UNDER REVIEW OR BEING CONSIDERED FOR EARLY PUBLICATION IN CORROSION MAGAZINE

Insulated Joints—By Dr. W. Beck, Department of Metallurgical Engineering, Lehigh University, Bethlehem, Pa.

Corrosion, Passivity & Passivation from the Thermodynamic Point of View—By M. Pourbaix, Journees des Etats de Surface, Paris, France.

Corrosion Problems in a Modern Fluid Catalytic Cracking and Fractionation Unit—By Nathan Schofer, Cities Service Refining Corp., Lake Charles, La.

A Case of Corrosion Involving Cinders—By C. H. Thompson, New York Telephone Co., New York, N. Y.

Crude Still Overhead System Corrosion—By A. F. Blumer, Esso Standard Oil Co., Louisiana Div., Baton Rouge, La.

Corrosion Problems in the Manufacturing of Sulfuric Acid—By T. L. Hart, National Zinc Co., Bartlesville, Okla.

Steam Reboiler Corrosion—By W. S. Janssen, Pan American Refining Corp., Texas City, Texas.

Value of Backfill With Carbon and Graphite Anodes—By J. P. Oliver, National Carbon Co., Cleveland, Ohio.

Preliminary Evaluation of Resinous Coatings—By W. R. Smith, Nukem Products Corp., Buffalo, N. Y.

Electrolysis Experiences on 115 KV High Pressure Oil-Filled Pipe Type Cable Installation in New Orleans—By S. E. Trouard, New Orleans Public Service, New Orleans, La.

Microscope As An Aid in Corrosion Problems—By H. M. Wilten, The Texas Company, Port Arthur, Texas.

Special Anodes for Cathodic Protection of Water Tanks—By A. L. Kimmel, Assistant Research Engineer, Engineering and Industrial Experiment Station, University of Florida, Gainesville, Fla.

The Effect of Various Aqueous Solutions Upon the Reactions At Pure Iron Anodes and Cathodes—By W. W. Kittelberger and A. C. Elm, New Jersey Zinc Co. of Pa., Palmerton, Pa.

Some Aspects of Buried Stainless Steel Pipe at the Hanford Works—By R. F. Plott, Associate Physicist, Argonne National Laboratory, Chicago, Ill.

Experience With Condenser Tubes at a Major Oil Refinery—By S. Van Der Baan, Corrosion Engineer, C. P. I. M. Refinery, Curacao, D. W. I.

Galvanic Corrosion in Oil and Gas Well Fluids*

By F. L. LaQUE

Introduction

THE PURPOSE of this article is to consider the possibilities of galvanic action in solutions such as may be encountered in oil and gas wells. In this connection, it seems to be as important to account satisfactorily for the frequent absence of galvanic effects where they might casually be anticipated as to discuss factors that influence the incidence and extent of galvanic action when it can occur.

Since economics dictates the choice of carbon or mildly alloyed steel for most oil and gas well equipment it is natural that attention should be focused on how galvanic action might influence the corrosion of steel which is likely to be the least noble metal and therefore subject to acceleration of its corrosion in any galvanic couples that may exist.

F. L. LaQUE

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Based on the author's own experience and reports from the field, galvanic corrosion in oil and gas well fluids is much less of a problem than might be anticipated from the use of so many different metals and alloys in electrical contact in liquids like oil well brines that are good electrolytic conductors. It seems, therefore, reasonable to proceed with the discussion of galvanic corrosion by considering factors that may be responsible for the frequent absence of any galvanic action in this service.

On the basis that the kind of corrosion with which we are concerned here is electrochemical in nature, it is reasonable to consider that galvanic corrosion is merely a particular form of such electrochemical corrosion where the anodic half of the corrosion reaction is concentrated on one metal and the cathodic half on another. The factors that influence normal corrosion also will influence galvanic corrosion but may be augmented by the greater driving force that can be developed in some galvanic cells as compared with the driving potentials of the local action cells that are involved in normal corrosion.

Galvanic Relationships

The potentials or voltages that can be developed by different couples are, of course, not simple properties of the metals involved but are influenced greatly by the nature of the electrolyte in which the couples may be exposed.

However, the relative positions of several metals and alloys remain the same in many electrolytes and data from observations in which sea water was the electrolyte will prvoide a reasonable basis for estimating the probable direction of galvanic effects in other environments, such oil well brines.

Table I shows the relative positions of a number of metals and alloys in sea water. Table II is based on data from Copson[1] and refers particularly to oil well materials tested in artificial sea water.

In addition to galvanic couples involving dissimilar metals there are, of course, similar couples that may be set up between steel carrying mill scale and steel from which the scale has been removed either wholly or partly. The magnitude of the potential that can be developed in such cells is considerable and seems to be influenced greatly by the temperature at which the scale is formed, as shown by the work of McCollam and Warrick,[2] who found a considerable increase in potential when the scaling temperature exceeded the critical temperature of the steel.

Another sort of self-contained galvanic cell sometimes is encounteded with cast iron when it develops a pronounced layer of graphitic corrosion product, such as illustrated in Figure 1. The potential developed between the iron and the graphite and its effect in accelerating corrosion are shown in Table III.

★A paper presented at the South Central Regional meeting of NACE, Tulsa, Oklahoma, September 20, 1948.

Effects of Polarization

Since the ultimate course of any corrosion cell will be influenced greatly by the combined effects of polarization at the anodic and cathodic surfaces, it is obvious that if such polarization is extreme enough both normal and galvanic corrosion will be stifled.

With steel in environments with which this article deals polarization at the cathodes is likely to be much more important than polarization at the anodes in determining the progress of corrosion. This is the situation that exists with such a couple as steel and copper in dilute sodium chloride as illustrated by polarization curves published by W. A. Wesley.[3]

Cathodic polarization will consist more frequently of accumulation of hydrogen at the cathodes. Such hydrogen may be removed by evolution as gas in which case corrosion is likely to be rapid, or it may be removed by reaction with oxygen at a slower rate.

The release of hydrogen as gas requires a certain minimum potential determined in part by the hydrogen ion activity of the solution and in part by the overvoltage characteristics of the surface upon which the hydrogen is released. Here then are possible mechanisms through which by themselves or together galvanic coupling may accelerate corrosion markedly:

1. The voltage of the galvanic couple may become sufficiently high to discharge hydrogen as gas from a solution in which the local action potential would not be high enough to evolve hydrogen.
2. The cathodic metal of the galvanic couple may have a relatively low hydrogen overvoltage and thus greatly favor the release of hydrogen as a gas.

It is obvious these mechanisms of hydrogen evolution may assume major importance in oxygen-free electrolytes so commonly encountered in oil and gas wells where hydrogen ion activity is so low the potential developed by uncoupled steel is not sufficient to evolve hydrogen to any considerable extent. It will be important, therefore, to examine the possibility that any galvanic couples likely to be encountered might cause corrosion of steel by hydrogen evolution under circumstances where corrosion of the uncoupled iron would be kept negligible by extreme cathodic polarization in the absence of oxygen.

Evidence of the controlling effect of hydrogen polarization of the local action cathodes in certain

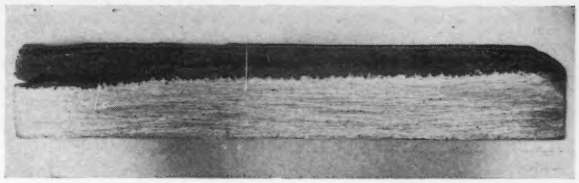


Figure 1—Cast iron with layer of graphite present after corrosion.

TABLE I

Galvanic series in sea water.

Magnesium	18-18-3 stainless steel type 316 (active)
Magnesium alloys	Lead
Zinc	Tin
Galvanized steel or galvanized wrought iron	Muntz metal
Aluminum 52SH	Manganese bronze
Aluminum 1S	Naval brass
Aluminum 3S	Nickel (active)
Aluminum 2S	Inconel (active)
Aluminum 53S-T	Yellow brass
Alclad	Admiralty brass
Cadmium	Aluminum bronze
Aluminum A17S-T	Red brass
Aluminum 17S-T	Copper
Aluminum 24S-T	Silicon bronze
Mild steel	Ambrac
Wrought iron	70-30 copper nickel
Cast iron	Comp. G-bronze
Ni-Resist	Comp. M-bronze
13% chromium stainless steel type 410 (active)	Nickel (passive)
50-50 lead tin solder	Inconel (passive)
18-8 stainless steel type 304 (active)	Monel
	18-8 stainless steel type 304 (passive)
	18-8-3 stainless steel type 316 (passive)

TABLE II

Galvanic series for oil-well materials in artificial sea water.

Anodic (corroded) end

Carbon steel: Grade "C", normalized; Grade "D", normalized; Grade "C", as rolled; Grade "D", plus molybdenum

Chromium-silicon-copper steel

SAE 4140

SAE 3140

14-to 18-percent chromium steel

Nickel

Brass

18-8 stainless steel

Cathodic (protected) end

TABLE III

Result of tests on the effect of a graphite layer on the corrosion of cast iron.

1. Normal Corrosion of Graphite Coated Cast Iron	74 mg. per sq. dm. per day
2. Normal Corrosion of Freshly Machined Cast Iron	167 mg. per sq. dm. per day
3. Corrosion of Freshly Machined Cast Iron in Contact with Equal Area of Graphite Coated Cast Iron (average over 9 day test)	535 mg. per sq. dm. per day
4. Initial Galvanic Corrosion Rate	6900 mg. per sq. dm. per day
5. Final Galvanic Corrosion Rate (Steady for last 5 days)	372 mg. per sq. dm. per day
6. Initial Open Circuit Potential	220 millivolts
7. Final Open Circuit Potential	35 millivolts
8. Initial Potential of Graphite Coated Cast Iron	440 millivolts*
9. Final Potential of Graphite Coated Cast Iron	658 millivolts*
10. Initial Potential of Freshly Machined Cast Iron	659 millivolts*
11. Final Potential of Freshly Machined Cast Iron	696 millivolts*

*Referred to saturated Calomel Half Cell

TABLE IV

Effect of conditions on corrosion rate of carbon steel in artificial sea water.

Temperature (Deg. F.)	Motion Ft. per Min.)	AERATION	H_2S Present	pH	Corrosion Rate of Carbon Steel (Mg. per Sq. Dm per day)
86	16	Saturated	No	8	57
120	16	Open to air, but no air added	No	5.5	82
120	16	Air content reduced by saturating solution with nitrogen or hydrogen	No	5.5	16
120	0	Solution covered with fuel oil	Yes	5	37
120	0	Saturated	Yes	5	94
120	16	Open to air, but no air added	Yes	3.5	335
120	100	No air added	Yes	3.5	1,000

oil well fluids was provided by Rogers and Shellshear[4] who found negligible corrosion of steel in oxygen-free waters in the pH range from 6.6 to 8.0 even when the waters contained hydrogen sulfide and salt. In acid brines corrosion may be appreciable by hydrogen evolution evidently favored by the sulfide corrosion products which perhaps facilitates hydrogen evolution. Similarly Copson[1] showed the effects of air on corrosion in artificial sea water as covered by the data in Table IV.

The foregoing data which established the importance of cathodic polarization and the oxygen content of the solution refer only to the corrosion of uncoupled iron where it is evident potentials of the local corrosion cells were not sufficient to produce hydrogen evolution in unaerated solutions. It is notable that while in aerated sea water corrosion of steel is accompanied regularly by some evolution of hydrogen, in air-free sea water there is no similar evolution of hydrogen.[5]

The possibility then remains that with the greater potential developed by a galvanic cell hydrogen evolution might occur in air-free solutions with a consequent gross acceleration of corrosion above that observed with uncoupled steel. Fortunately information is available to dispose of this possibility from the classic experiments of O. P. Watts.[6]

Watts made up galvanic couples of several metals and alloys and sealed them carefully in vessels containing solutions from which all traces of oxygen had been removed by a combination of evacuation and sweeping out with either carbon dioxide or nitrogen.

Data of particular interest here were secured from Watts' tests using oxygen-free sodium chloride and seat water as the electrolytes and are summarized in Table V.

TABLE V

Couples* which showed no evidence of galvanic corrosion after exposure for 310 to 440 days by O. P. Watts.

Couple	Electrolyte	pH	Duration of Test Days
Iron-Brass	0.5 Normal NaCl + CO_2	3.9	402
Iron-Copper	0.5 Normal NaCl + CO_2	3.9	402
Iron-Monel	0.5 Normal NaCl + CO_2	3.9	382
Iron-Gold	0.5 Normal NH_4Cl + CO_2	4.4	333
Iron-Graphite	Oxygen-free sea water	....	310
Iron-Monel	Oxygen-free sea water	....	326

* Areas of iron and other metals in couples were equal.

In view of the importance of CO_2 in the distillate well corrosion problem it seems especially significant that in the absence of oxygen the presence of CO_2 did not bring on any galvanic corrosion in the couples tested in Table V.

It should be noted here, however, that corrosion can and does occur in distillate wells where the condensate contains CO_2 but practically zero oxygen. Similarly Eilerts and his associates[7] observed acceleration of corrosion of steel when coupled with either copper or nickel in their CO_2 saturated solutions which contained little or no air. It would appear, therefore, that with the large amounts of CO_2 present in solutions under pressure, corrosion of steel can proceed presumably by hydrogen evolution, in the absence of oxygen. However, in practice, rapid corrosion of steel appears to be confined to areas where the surface of the steel is kept clean by erosion by liquid or gas moving at high velocity. From this it follows that this corrosion reaction probably is under anodic rather than cathodic control and galvanic coupling would cause acceleration of corrosion of steel in the air-free solution only if the other circumstances were favorable to such action. These other necessary circumstances would include:

1. Depolarization of the steel surfaces (protective film removal) by erosive effects.
2. A continuous body of electrolyte sufficient to cover a substantial area of the more noble metal in contact with the steel.

The experiments of Copson[1] mentioned previously also demonstrated that galvanic action among oil well materials would be negligible in brines and drilling mud containing little or no dissolved oxygen. These data are shown in Tables VI and VII from which it would appear that the presence of the mud tends further to stifle galvanic action as well as normal corrosion. The fact that in tests covered by Table VI corrosion of Grade C steel was accelerated only slightly more by coupling it with nickel with an open circuit potential of 340 millivolts than by coupling it with a low alloy steel with an open circuit potential of only 50 millivolts, provides further evidence of the controlling effect of cathodic polarization in such an environment.

The evidence just presented should serve to account for absence of galvanic action in oil or gas well fluids that are substantially free from oxygen and not acid enough to favor release of hydrogen as a gas.

Effects of Relative Areas of Resistance

Where there is aeration there may be other factors that often will retard galvanic action to a tolerable limit. For example, there is the area effect. Where the corrosion reaction is under cathodic control, which is commonly the case, the extent of galvanic acceleration of the corrosion of the anodic material will be determined by the relationship between the area of the cathodic material and the area of the anodic material as illustrated for iron and copper in sodium chloride by Figure 2. Consequently where the exposed area of the cathodic material is relatively small the galvanic action may be negligible. Examples are

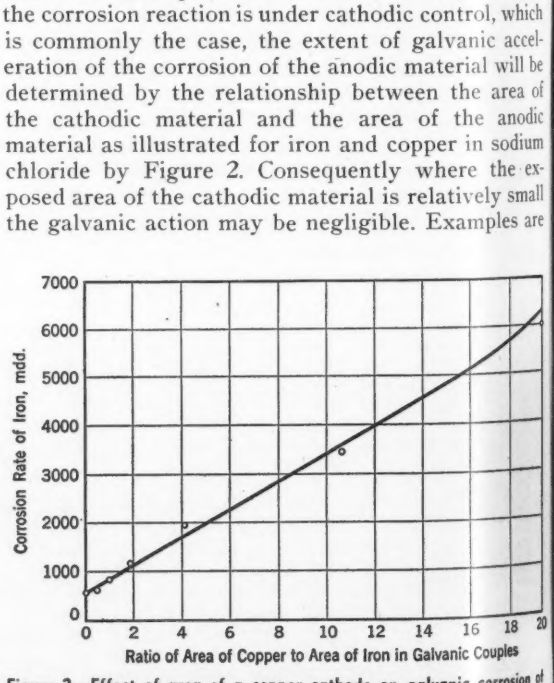
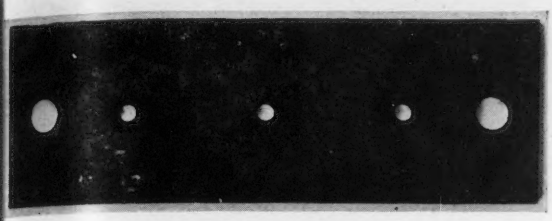
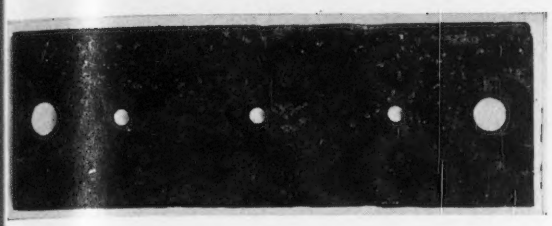


Figure 2—Effect of area of a copper cathode on galvanic corrosion of iron anode in aerated 3 percent sodium chloride. Area of iron anode—0.047 sq. dm. Area of copper cathodes—0.024 to 0.94 sq. dm.



Bolted with Monel bolts.



Exposed without bolts—control.

Figure 3—Mild steel panels exposed with Monel bolts and without bolts after exposure to flowing sea water at Kure Beach, N. C., for 11 months.

provided by Monel fastenings in contact with a steel plate in aerated sea water, as illustrated in Figure 3, which shows no evidence of accelerated corrosion of the steel where it had been in contact with the Monel bolt, nut and washer assemblies. Similarly, carbon and low alloy steel plates welded with 25 Cr-20 percent Ni austenitic stainless steel welding rods showed no acceleration of corrosion alongside welds after exposure in sea water for over two years. This is illustrated by Figure 4.

And then there is the resistance effect. A galvanic cell will obey Ohm's law and the current that can flow, with its attendant corrosion, will be limited by the resistance of the electrical circuit as well as by the polarization effects previously mentioned. The relationship between circuit resistance and galvanic current and corrosion of couples of iron and copper in sodium chloride is shown by Figure 5 based on data from W. A. Wesley.[3] It is especially significant that the first small increase in resistance has the greatest effect in reducing the galvanic current.

This resistance effect also includes, of course, the resistance of the electrolyte as well as that of the metallic contact between the dissimilar metals. The resistance of the electrolyte is important not only through its direct effect but also indirectly by limiting the area of the cathodic material that will play a part in the galvanic cell when the contact between the dissimilar metals is along a line. An example of this is provided by Copson's[8] experiments with iron and steel in tap water, as illustrated by Figure 6. In poorly conducting solutions galvanic action, while localized near the contact, also will be restricted in extent by the limited area of cathodic material available to take part in the action. It is wrong to assume that galvanic action will be more severe in poor electrolytes than in good ones, even though it may be more localized near the contact.

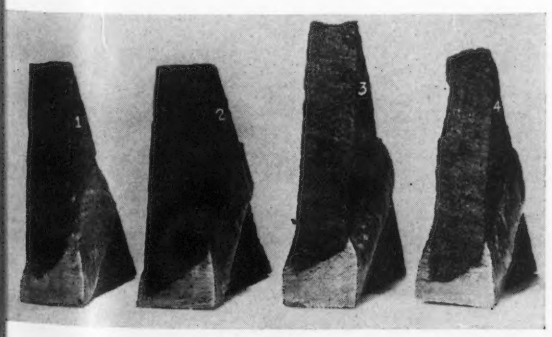


Figure 4—Sections cut from austenitic stainless steel welds in low alloy steel (left) and carbon steel plates (right) after exposure to flowing sea water for two years.

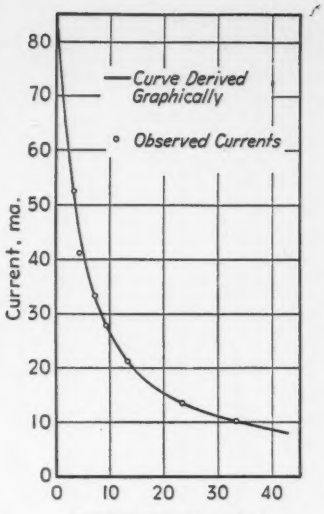


Figure 5—Effect of resistance on galvanic corrosion.

In good conductors, with the action under extreme cathodic polarization control, the nature of the cathodic material and the open circuit potential of the galvanic cell will have little effect on the extent of galvanic action, as illustrated by the data in Table VI already mentioned. However, in poorer conductors the open circuit potential will be more important both directly in overcoming the resistance effect and

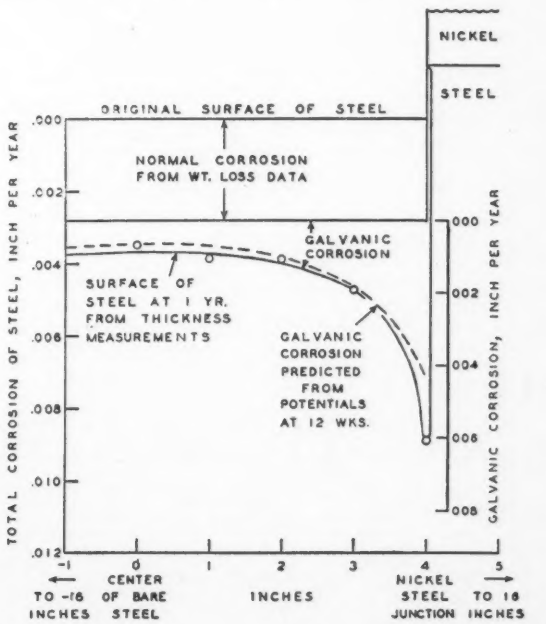


Figure 6—Distribution of galvanic corrosion in nickel-to-steel couple in Bayonne tap water as shown by a cross section through nickel-clad steel with part of the cladding removed.

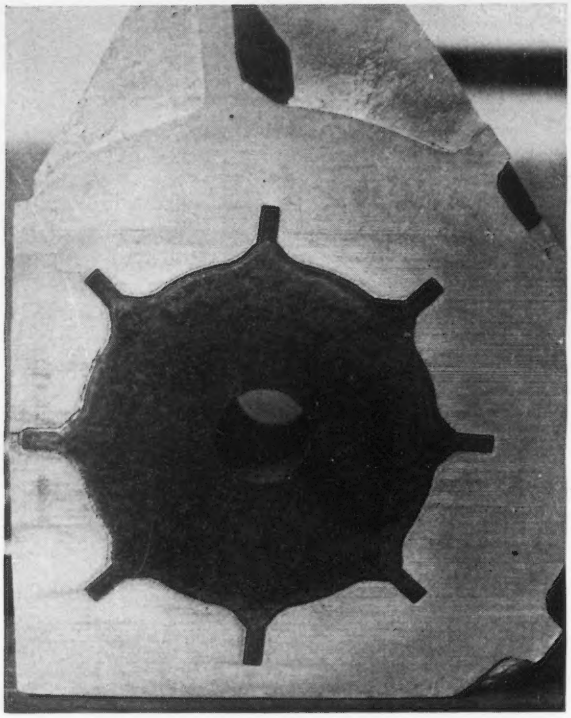


Figure 7—Galvanic corrosion at contact of steel insert with magnesium casting after exposure in marine atmosphere for 2.5 years.

in enlarging the effective area of the cathodic material.

The effect of a high resistance electrolyte in limiting the extent of galvanic action is illustrated also by Figure 7 showing a combination of magnesium and iron exposed to a marine atmosphere.

Practical Application of Principles

Galvanic action also may be stifled in some instances by the presence of inhibitors such as chromates which may passivate iron to the potential of more noble materials as demonstrated by H. R. Copson[9] for combinations of nickel and steel in water.

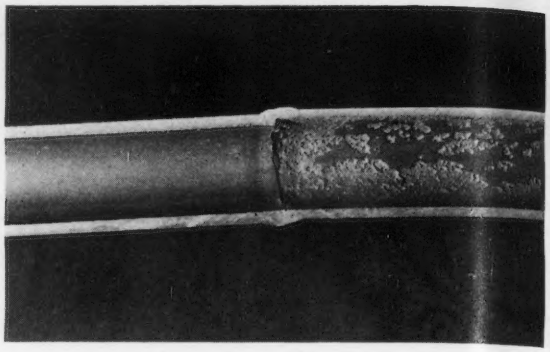


Figure 8—Joint between nickel plated (unattacked) and steel (attacked) tubing after over a year in distillate well line. Note absence of galvanic action at, or near, contact of nickel and steel.

To illustrate the practical application of some of the principles discussed it can be concluded that tubing made of alloy steel or even a material as noble as stainless steel, nickel plated steel or Monel, could be placed inside a carbon steel casing without introducing any risk of significant accelerated corrosion of the latter. The reasons would be:

1. The electrolyte between the tubing and casing would be substantially free from oxygen and the galvanic cell would be stifled quickly by cathodic polarization.
2. The area of the more noble tubing material would be less than that of the casing so at the worst the galvanic corrosion of the casing would be limited to something less than twice its normal rate of corrosion, which usually would be tolerable.

It also seems unlikely that there would be much acceleration of corrosion of steel exposed at accidental bare or worn spots in electro-deposit nickel coating such as has been used in sucker rods and distillate well tubing. In the case of the sucker rods, the reason is again the low oxygen content of the fluid and perhaps also the discontinuity of the brine phase in the oil. In the case of the distillate well tubing, it appears the corrosive liquid occurs as thin films or isolated drops that sweep over the metal surfaces.

TABLE VI

Galvanic-corrosion tests in artificial sea water.

	COUPLES 1 THROUGH 10	COUPLE 13
Solution	Artificial sea water	
Volume	4 liters	
Temperature	120 deg. F.	
pH	5.1 to 5.8	
Motion	16 ft. per minute	
Ratio of cathode to anode area	1	
Time, total	673 hours	211 hours
Time, galvanic	647 hours	198 hours
Aeration	No air added	Reduced by stream of nitrogen for 6 days and of hydrogen for 3 days

Couple	Anodic Material	Cathodic Material	Areas (Square Decimeters)		Average Open-Circuit Potential (Volts)	Average Potentials Against Saturated-Calomel Half-Cell (Volts)				Average Galvanic Current (Milliamperes per Square Decimeter)	Weight Losses (Mg. per Sq. Dm. per Day)				Galvanic Corrosion of Anode (Mg. per Sq. Dm. per Day)		Total Weight Loss of Anode Plus Cathode (Mg. per Sq. Dm. per Day)
						Anodic Material		Cathodic Material			Anodic Material		Cathodic Material				
			Anodic Material	Cathodic Material		Insulated	Coupled	Insulated	Coupled		Insulated	Coupled	Insulated	Coupled	From Weight Loss	From Current	
1	Grade "D," normalized	SAE 4140	1.13	1.13	0.07	—0.76	—0.75	—0.73	—0.71	2.16	71	112	56	17	44	54	65
2	Grade "D," normalized	SAE 3140	1.13	1.13	0.10	—0.74	—0.73	—0.69	—0.66	3.30	72	140	67	12	71	83	76
3	Grade "D," normalized	Grade "C," as rolled	1.13	1.13	0.001	—0.76	—0.76	—0.76	—0.76	0.07	69	73	86	76	4	2	75
4	Grade "C," as rolled	Grade "D," plus molybdenum	1.13	1.13	0.001	—0.77	—0.76	—0.76	—0.76	0.18	90	91	93	90	2	4	91
5	Grade "C," as rolled	Cr-Si-Cu steel	1.13	1.10	0.05	—0.77	—0.76	—0.74	—0.73	2.07	79	110	45	20	32	52	65
6	Grade "C," normalized	Grade "C," as rolled	1.13	1.13	0.001	—0.77	—0.77	—0.77	—0.77	0.08	73	74	66	63	1	2	69
7	Grade "C," as rolled	18-8 stainless	0.31	0.26	0.59	—0.73	—0.73	—0.16	—0.14	1.34	81	104	2	0.2	24	34	52
8	Grade "C," as rolled	Nickel	0.31	0.31	0.34	—0.70	—0.71	—0.26	—0.39	1.66	69	158	23	1	92	42	80
9	Grade "C," as rolled	Brass	0.31	0.31	0.42	—0.70	—0.71	—0.25	—0.26	1.99	89	142	47	1	56	50	72
10	Grade "C," as rolled	14- to 18-percent chromium steel	0.31	0.31	0.38	—0.74	—0.74	—0.42	—0.36	1.95	127	175	41	1	50	49	88
13	Grade "D," normalized	SAE 3140	1.13	1.05	0.04	—0.77	—0.78	—0.75	—0.74	0.30	16	24	17	0.2	8	7	..

TABLE VII

Galvanic-corrosion tests in Anahuac drilling mud.

Solution	Anahuac drilling mud	Motion	16 ft. per minute
Volume	4 liters	Time, total	672 hours
Temperature	120 deg. F.	Time, galvanic	662 hours
pH	8.9	Ratio of cathode to anode area	1
Aeration	No air added		

Couple	Anodic Material	Cathodic Material	Areas (Square Decimeters)		Average Open-Circuit Potential (Volts)	Average Potentials Against Saturated-Calomel Half-Cell (Volts)				Average Galvanic Current (Milliamperes per Square Decimeter)	Weight Losses (Mg. per Sq. Dm. per Day)				Galvanic Corrosion of Anode (Mg. per Sq. Dm. per Day)		Total Weight Loss of Anode Plus Cathode (Mg. per Sq. Dm. per Day)
						Anodic Material		Cathodic Material			Anodic Material		Cathodic Material				
			Anodic Material	Cathodic Material		Insulated	Coupled	Insulated	Coupled		Insulated	Coupled	Insulated	Coupled	From Weight Loss	From Current	
11	Grade "D," normalized	SAE 4140	1.06	1.05	0.01	−0.82	−0.82	−0.81	−0.81	0.12	10	12	12	7	2	3	10
12	Grade "D," normalized	SAE 3140	1.10	1.03	0.05	−0.82	−0.83	−0.79	−0.78	0.39	12	18	14	2	6	9	10

The electrical resistance of such an electrolyte is high, which limits not only the galvanic current but the area of the nickel that can take part in the cell. Thus the indications of the experiments of Eilerts and his associates[7] with combinations of iron and copper and iron and nickel immersed in carbon dioxide saturated water cannot be applied directly because of the difference in the condition of the electrolyte. This is supported by the absence of any significant acceleration of corrosion of steel near its contact with nickel in a distillate well line, as shown in Figure 8.

Of course there may be circumstances in oil and gas wells where conditions will be more favorable to galvanic action than those discussed here—but it seems that these will involve one or more of the following conditions:

1. A highly acid environment in which corrosion of iron can proceed vigorously in the absence of oxygen.
2. A well-aerated solution in which corrosion can proceed with or without hydrogen evolution.
3. A ratio of area of cathode to area of anode greater than 1.
4. A continuous electrolyte of good conductivity.
5. A high degree of turbulence or erosive action where the normal corrosion of steel appears to be controlled by such factors.

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Protective Films

Natural Formation on Aluminium and its Alloys*

By F. A. CHAMPION*

THE PROTECTIVE films formed on metals in corrosive environments play an important role in the mechanism of corrosion with most metals. Aluminium has a very high affinity for oxygen and the unconstrained volume of the resulting oxide is greater than that of the metal. A thin, hard, compact, adherent, and self-healing alumina film is therefore rapidly formed on aluminium and its alloys so that they show resistance to corrosion of a very high order. In view of the unusually protective character of the alumina film it is not surprising that Evans[1] has found difficulty in including aluminium in his theory of the mechanism of oxidation and tarnishing of the common metals. This article is not concerned with the theory of the formation of such films, but is intended to review the quantitative experimental data on the formation of alumina films on aluminium and its alloys and to consider the practical implications of the information so obtained. The term corrosion is used in its widest sense to include any conversion of aluminium into alumina (which is essential for protective film formation) or other corrosion products. The thicker films resulting from artificial stimulation of the film formation, for example by anodic treatment in a suitable electrolyte, are not considered.

The nature and thickness of the film formed depends on the environment to which the metal is exposed, the thicker, more protective films tending to be formed in the more corrosive environments. Thus the film formed by simple exposure of aluminium to air is usually inadequate for protection against corrosion by natural waters, so that a new film is formed on immersion in the latter. The formation of such films involves the conversion of metallic aluminium to alumina, but the consequent attack on the metal is often negligible. In some media, however, appreciable corrosion occurs before the corrosion rate has been reduced to a negligible value by the formation of the film. In any case it is to be expected that the corrosion rate, whether appreciable or not, will tend to decrease with increasing time of exposure. The form of the corrosion-time curve must be considered, therefore, in the design of corrosion tests if reliable predictions of service behaviour are to be made from the results. Accurate knowledge of the form of the curves is of great value for this purpose. Further research is desirable in this connection, but the information already available permits the design of routine corrosion tests on this basis.

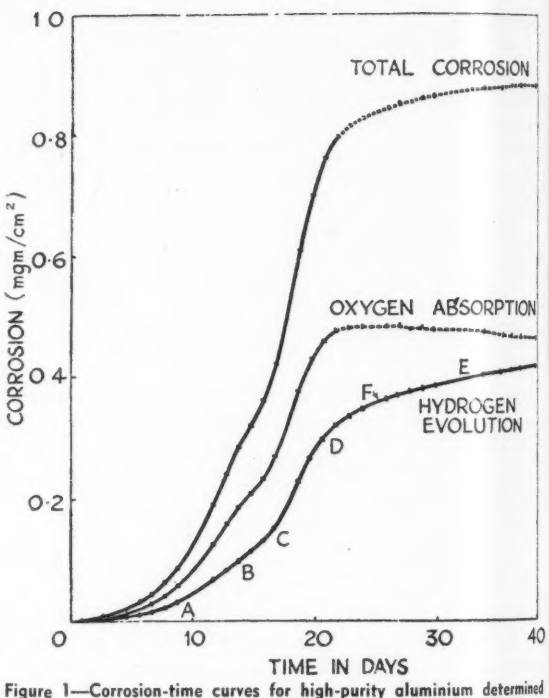

Figure 1—Corrosion-time curves for high-purity aluminium determined by the gasometric method.

Films in Aqueous Solution

The author[2] has studied the corrosion-time curves of aluminium of very high purity by means of the gasometric method developed by Bengough, Stuart and Lee.[3] The specimens were machined, annealed and degreased before totally immersing in a horizontal position in normal potassium chloride solution at a pH of about 5.5 under an atmosphere of purified oxygen. The hydrogen evolved and oxygen absorbed by the corrosion process were measured periodically and the total corrosion after each period was calculated from these results. Typical results are shown in Figure 1. Hydrogen evolution accounted for 35-40 percent of the total corrosion, and could be accurately measured throughout each experiment, whereas experimental difficulties sometimes made accurate measurement of the low rate of oxygen absorption impossible, especially on prolonged expo-

★ Reprinted from Metal Industry, May 28-June 4 (1948).

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sure. Figure 2 showing the relation of the corrosion rate (graphically determined from Figure 1) to the corrosion is therefore restricted to the hydrogen evolution curve, but the total corrosion curve appeared to be similar in form. The results of this work have been discussed in detail elsewhere,[2] but the main features are as follows.

Initially the solution is saturated with oxygen and free from hydrogen, so that a little time is taken in establishing concentration gradients through the solution for these gases between the metal and the gas/solution interface. Figure 2 shows that the corrosion rate $\frac{dy}{dt}$ then increases in direct proportion to the corrosion (y) which has previously occurred, i.e.

$$\frac{dy}{dt} = \beta + \alpha y \qquad \text{I}$$

where β is the initial rate and α represents the acceleration of corrosion. After passing through the maximum the corrosion rate decreases again in direct proportion to the corrosion which has already occurred:

$$\frac{dy}{dt} = \beta - \alpha y \qquad \text{II}$$

but there is a change in the values of the parameters α and β at F in Figures 1 and 2.

By integration of equation II we have

$$y = \frac{\beta}{\alpha}\left[1 - e^{-x(t-t_0)}\right] \qquad \text{III}$$

where $y = 0$ when $t = t_0$
and $y = \beta/\alpha$ when $t = \infty$
so that β/α is the ultimate corrosion to be expected if corrosion proceeds indefinitely according to equation III and may be represented by y_∞, so that equation III becomes,

$$y = y_\infty\left[1 - e^{-\alpha(t-t_0)}\right] \qquad \text{IV}$$

There is an imaginary value of y_∞ to be deduced from the portion D of the curves in Figures 1 and 2 and a real value to be deduced from portion E.*

It was characteristic of these empirical curves that the point F always occurred when $y/y_\infty = 0.79 \pm 0.03$ which suggests that a definite stage in film formation is reached at that point.

There is a break in the curves at B which is attributed to differences in the conditions on the top and bottom surfaces of the specimens, and which should therefore be absent from curves for more uniform corrosion conditions. The portions A and C of the curve in Figure 2 should then form a continuous straight line representing an induction period. Thus curves of this type were obtained by H. H. Podgurski[4] from measurements of hydrogen evolution and oxygen absorption with pure aluminium partially immersed in distilled water saturated with oxygen. The measurement of hydrogen evolution was sufficiently accurate to permit graphical analysis of the results, which showed the curve to be precisely of the form shown in Figures 1 and 2, except that there was no indication of the break at B. The change in slope corresponding to F occurred when $y/y_\infty = 0.76$ which agrees well with the above value of 0.79. Curves of

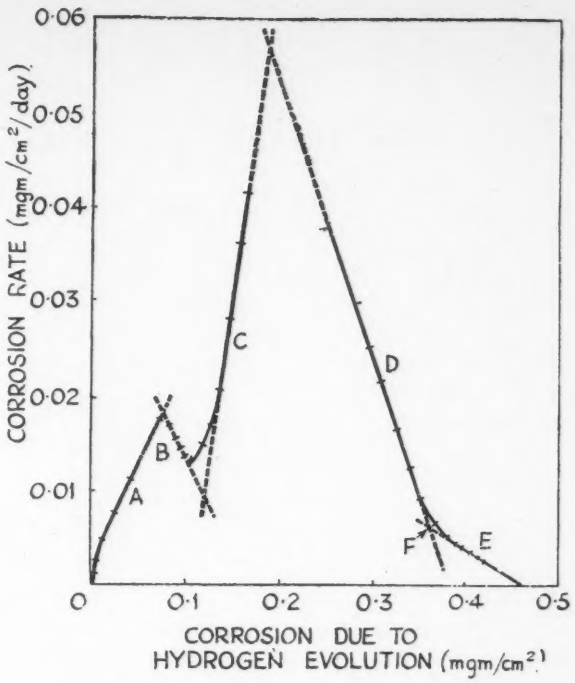

Figure 2—Analysis of hydrogen evolution curve of Figure 1.

this type were also obtained by Bryan and Morris[5] for high-purity (99.992 per cent.) aluminimum in an alkaline buffered solution of pH 10.78 in the presence and absence of oxygen. In this case corrosion was assessed by determining the loss of weight of successive specimens exposed for different periods: in consequence of the lower accuracy (as compared with the gastrometric method) and the practical difficulty of obtaining frequent determinations by this method, the resulting curves are not suitable for detailed mathematical analysis. However, they clearly show the initially increasing and subsequently decreasing corrosion rate without the break at B. Similar tests on aluminum of lower purities (99.8 per cent 99.5 per cent 99.2 per cent) showed[5,6] that the maximum corrosion rate was reached more quickly (i.e. the inducting period became less marked) as the purity decreased. With the 99.2 per cent purity no induction period was observed and the curve conformed to equation IV from the commencement of exposure. Moreover with these less accurate curves the abrupt change in slope corresponding to the point F of Figures 1 and 2 was not detectable.

This simpler form of curve is also observed when the corrosion of aluminum alloys is assessed by the loss of mechanical properties. This is illustrated in Figure 3 in which the loss of mechanical properties of various aluminum alloys exposed under various conditions by several investigators[7,8,9] is plotted against the time of exposure. Curves to equation IV (with constant parameter values) have been fitted to these empirical points (full lines of Figure 3). An induction period is indicated in one case (curve e), but the method of asessment is not sufficiently sensitive to show the increasing corrosion rate in this

* This exponential equation also has been observed for the corrosion of zinc under some conditions.[2, 3]

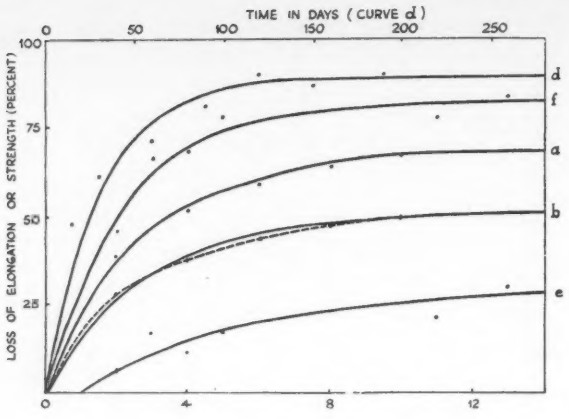

Figure 3—Corrosion-time curves for various alloys.

period. The author's results[9] and those of other workers[10] lead to similar conclusions while Dix[11] arrived at similar but less precise conclusions.

The curves e and f of Figure 3 were derived from specimens which had been corroded while stressed by bending to a constant curve (giving constant strain).[7] Comparison with control specimens exposed to similar conditions, except that they were not stressed, showed that the stress accelerated corrosion. In spite of this complication of the corrosion conditions, Figure 3 shows that the exponential equation still applies. There is evidence from laboratory experiments[12] that if an alloy of aluminum and 7 per cent magnesium in a certain condition is corroded while stressed in tension by a constant load the rate of loss of mechanical properties increases immediately before failure so that the exponential equation ceases to apply. This is probably due to the severe stress conditions preventing the protective film from fulfilling its normal function.[13] The phenomenon very rarely occurs in service. Similarly if the corrosion conditions are too severe to permit the presence of the alumina film, as for example when the metal is immersed in strong hydrochloric acid, then again the exponential equation is not applicable.

Localized corrosion is often assessed by measuring the depth of the deepest pit but this is an unreliable criterion for the purpose. It seems probable that the frequency of pits of various depths on a specimen conform to the normal distribution law and that the depth which is exceeded by 2.5 per cent of the possible population of pits provides a better measure of the danger of perforation of a metal by pitting: this depth has been termed the "perforation factor."[14]

The methods at present available for assessing this factor with aluminium do not offer a high order of accuracy, but the results obtained are compatible with the view that localized corrosion of aluminium conforms to the exponential law. For example the values of the "perforation factor" for pure aluminium exposed in a salt spray test are plotted in Figure 4 against the time of exposure and a curve to equation IV is drawn to these points.

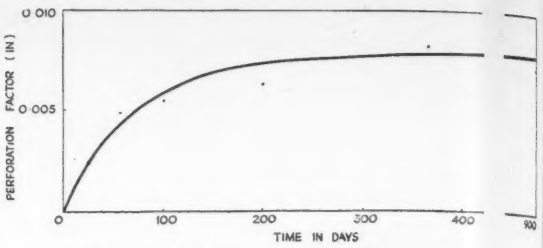

Figure 4—Corrosion-time curve for pitting of aluminium.

Air-Formed Films

The only information available on the formation of the film on bare aluminium appears to be that obtained by Steinheil.[15] Pure aluminium was condensed on to mica in vacuum, and oxygen was then admitted. The increase in transparency due to oxidation of the metal was observed and the thickness of the alumina film was calculated from the results. The results from one experiment are given in Table I together with the values calculated from the exponential equation IV and the logarithmic equation.[16]

$$t = ae^{by} \qquad \text{IV}$$

The values of the parameters which give the calculated values of Table I are:

$$\begin{aligned} a &= 6 \times 10^{-6} \\ b &= 500 \\ \alpha &= 0.0505 \\ t_o &= 20 \\ y_\infty &= 0.0440 \end{aligned}$$

It will be seen that the oxidation for about the first two hours closely follows the logarithmic equation V. The only other experiment quoted by Steinheil was of less than two hours duration and also conformed closely to the logarithmic equation. After about two days the experimental values in Table I are in close accordance with the exponential equation IV. The values observed between two hours and

TABLE I

Exposure of Oxide-Free Aluminium to Oxygen

TIME	THICKNESS OF OXIDE FILM (y in Microns)		
	Expt. Values	Calculated Values	
		Equation V	Equation IV
2.3 mins.	0.0104	0.0111	.....
2.6 mins.	0.0114	0.0114	.....
3.7 mins.	0.0117	0.0121	.....
4.8 mins.	0.0128	0.0126	.....
5.8 mins.	0.0132	0.0130	.....
6.3 mins.	0.0130	0.0132	.....
8.3 mins.	0.0135	0.0137	.....
9.6 mins.	0.0134	0.0140	.....
17.6 mins.	0.0149	0.0151	.....
18.7 mins.	0.0154	0.0153	.....
20.2 mins.	0.0152	0.0154	.....
20.7 mins.	0.0149	0.0155	.....
22.0 mins.	0.0149	0.0156	.....
34.7 mins.	0.0170	0.0166	.....
54.7 mins.	0.0175	0.0175	.....
108 mins.	0.0188	0.0188	.....
0.84 days	0.0263	0.0234	0.0296
1.75 days	0.0290	0.0249	0.0303
3.71 days	0.0316	.....	0.0316
4.72 days	0.0322	.....	0.0322
5.80 days	0.0330	.....	0.0329
7.81 days	0.0340	.....	0.0341
8.79 days	0.0343	.....	0.0347
11.95 days	0.0364	.....	0.0361
12.95 days	0.0368	.....	0.0369
15.15 days	0.0375	.....	0.0374
19.0 days	0.0384	.....	0.0386
20.0 days	0.0390	.....	0.0389
30.0 days	0.0410	.....	0.0410

two days are intermediate between those calculated from the logarithmic and exponential equations thus indicating a gradual transition. Lustman[17] has pointed out the application of the logarithmic equation to Steinheil's results, and appears to regard it as applicable for the whole period of exposure. Examination shows, however, that even allowing for a change in parameters of the equation at about 1.75 days the fit for the subsequent results is not as good as is given by the exponential equation IV. There is no indication of a change in slope in Steinheil's curves corresponding to that at F in Figures 1 and 2. Evidently this point had not been reached when the measurements were discontinued.

Vernon[18] measured the gain in weight of 99.98 per cent and 99.6 per cent rolled aluminium on exposure to London air. In spite of careful cleaning with a steel wire brush there can be no doubt that the specimens already carried a very thin air-formed film at the beginning of exposure by Vernon. The values taken from Vernon's graphs for experiments A and B are given in Table II together with the corresponding values calculated from equation IV, including the ultimate corrosion (y_∞, imaginary and real), the corrosion (y_F) at the time of the change in parameter values, and the ratio of these. The close agreement between the experimental and calculated values (especially in experiment B) demonstrates the applicability of the exponential equation IV while further evidence of this is given by the agreement between the values of the ration y_F/y_∞ shown in Table II and the mean value (0.79) observed by the author for immersed aluminium. The third corrosion time curve (C) published by Vernon is given with less accuracy and has not been quantitatively examined although it appears to be similar to A and B.

It will also be seen from Table II that the values of t_0 in equation IV were —0.5 and —0.75 for experiments A and B respectively thus showing that the exponential curve cut the corrosion axis. Thus the initial gain in weight prior to Vernon's first observations after 0.4 days did not follow the exponential equation, but probably followed the logarithmic equation V as in the first 0.2 days of Steinheil's experiments.

On continuing exposure of his specimens beyond the period considered in Table II, Vernon observed breaks in the curves, each successive break being less marked than its predecessor. These breaks occurred on the same date in the three different experiments (A, B and C), irrespective of the time for which the specimens had been exposed, thus indicating that they were due to variations in exposure conditions. Vernon suggested that these breaks were due to cracking and subsequent self repair of the film, but they may possibly be merely a thickening of the film in response to an increase in the severity of the corrosion conditions as already referred to. Evans[1] assumes those breaks to be due to flaking of the alumina film, but Vernon apparently did not observe such flaking and the present author has never observed such flaking on aluminium.

Evans[1] states that Vernon has suggested that attempts to fit curves to the latter's results are not justified, since the experiments, designed for another purpose, were not carried out under conditions of constant temperature, humidity and atmospheric pollution. The present author considers however, that the agreement of Vernon's values with those calculated from an equation shown to be widely applicable to aluminium and its alloys, and the agreement in the position of the point F in Vernon's, Podgurski's and the author's experiments, amply justify the curve fitting from which Table II has been derived.

TABLE II

Atmospheric Exposure of Aluminium

TIME (Days)	WEIGHT INCREMENTS (y, mgm./sq. dm.) 99.98% Purity (Expt. A) Expt. Values	Calculated Values		99.6% Purity (Expt. B) Expt. Values	Calculated Values	
—0.75	.....	.....	.....	.....	0.000	.....
—0.5	.....	0.000	.....	.....	.....	.....
0.4	0.066	0.061	.....	0.090	0.089	.....
1.0	0.096	0.090	.....	0.122	0.123	.....
2.0	0.116	0.121	.....	0.157	0.164	.....
3.0	0.136	0.140	.....	0.188	0.190	.....
4.0	0.156	0.154	.....	0.207	0.208	.....
6.0	0.170	0.168	.....	0.227	0.228	.....
8.0	0.175	0.175	0.175	0.241	0.238	.....
10.0	0.181	.....	0.178	0.240	.....	0.244
13.0	.....	.....	.....	0.254	.....	0.255
14.0	0.185	.....	0.185	0.261	.....	0.259
27.0	0.188	.....	0.194	0.288	.....	0.286
34.0	0.199	.....	0.199	0.293	.....	0.294
y_∞ =	.....	0.180	0.210		0.245	0.305
y_F =	.....	0.174			0.240	
y_F/y_∞ =	.....	.....	0.83			0.79

Practical Implications

It will have been seen from the above discussion that there is considerable evidence to support the view that whenever an alumina film can be formed and maintained on the metal the corrosion of aluminium and its alloys follows an exponential law, except for the initial stages of formation of the film in air or oxygen which are of no practical importance, and the oxidation of aluminium at high temperature.[19] Moreover the author is not aware of any sound evidence against this view. For practical purposes the corrosion-time curves may be regarded as following equation IV without change in the parameter values, but there may be an initial induction period during which no corrosion is observed.

The parameters (α, β and $y_\infty = \beta/\alpha$) of the exponential equations (III and IV) therefore provide the most reliable and concise method of expressing the corrosion behaviour of aluminium and aluminium alloys. Having established the general applicability of the equation these parameters may be deduced from relatively few experimental observations. The following logarithmic method[9] of calculation simplifies the procedure.

From equation IV we have

$$\log_{10}\frac{y_\infty - y}{y_\infty} = \frac{-\alpha(-t_0)}{2.3} \qquad \text{VI}$$

If values y_1 and y_2 be taken such that the corre-

sponding times are related by the following equation:

$$2(t_1 - t_0) = (t_2 - t_0)$$

$$\text{then } \log \frac{y_\infty - y_2}{y_\infty} = 2 \log \frac{y_\infty - y_1}{y_\infty}$$

$$\text{or} \qquad y_\infty = \frac{y_1^2}{2y_1 - y_2} \qquad \text{VII}$$

The curve b of Figure 3 may be taken as an example of the use of equations VI and VII. A free-hand curve (broken line) is drawn to the empirical points and pairs of values of y_1 and y_2, as defined above, are read from this curve. Several values of y_∞ and hence a mean value ($\bar{y}_\infty$) are then calculated by equation VII as shown in Table III. The values of ($\bar{y}_\infty - y$) calculated from the empirical values of y are then plotted against the corresponding values of t (on semi-log paper).

A straight line is drawn to represent equation VI and values of y and t may be derived from this line for plotting the final curve (full line curve b) as in Figure 3, and for calculating the remaining parameter values by equation VI:—

$$\alpha = \frac{2.3}{t - t'} \log_{10} \frac{y_\infty - y'}{y_\infty - y}$$

$$\beta = \alpha y_\infty$$

This procedure is illustrated in Figure 4. The curve shown was drawn when the test had been in progress only for one year and was therefore based on the values obtained from exposure periods up to 400 days. It will be seen, however, that the value subsequently obtained from 900 days exposure was in reasonable agreement with that curve, bearing in mind that a high order of accuracy cannot be expected from the method of assessment employed.

Thus the ultimate corrosion, which is usually the most important parameter, can be determined by extrapolation from tests of much shorter duration than would be required for direct observation. This provides a more reliable method of expediting results than is afforded by the more usual practice of accelerating the corrosion process itself, for example by adding considerable amounts of acid or hydrogen peroxide to salt solutions.

On the other hand it is evident that since corrosion follows the exponential equation the other common practice, of assessing the corrosion which has occurred after a single arbitrary period of time, is not a reliable method for determining the corrosion behaviour of aluminium and its alloys. The corrosion should be determined after several periods of exposure, specimens being withdrawn from test for the purpose if necessary and the periods preferably increasing approximately in geometrical progression.

TABLE III

The Calculation of y_∞ for Curve b of Figure 3

$(t_1 - t_0)$	$(t_2 - t_0)$	y_1	y_2	$y_\infty = \frac{y_1^2}{2y_1 - y_2}$	y_∞
3.2	6.4	35	45	49	51
4.0	8.0	38	47.5	51	
5.0	10.0	41	50	52	

The form of the corrosion time curve should also be borne in mind in more casual observations of the corrosion behaviour of aluminium and its alloys in service. Thus alarm may be felt sometimes on observing the corrosion of aluminium chemical plant during the initial period of use, but if the plant has been correctly designed this corrosion, whether general or localized, will cease in accordance with equation IV before it has become of practical importance. As a familiar example of this, many people are using aluminium domestic utensils which show no more corrosion after twenty years continuous use than they did after the first few months of use.

Summary

The alumina film formed on aluminium and its alloys on exposure to air and other corrosive environments is responsible for the high corrosion resistance of these metals and controls the form of the corrosion-time curve. The term corrosion is used in its widest sense to include any conversion of aluminium into alumina (which is essential for protective film formation) or other corrosion products.

On exposure of the bare metal to oxygen the film formation during the first two hours at normal temperature folows the logarithmic law. A gradual transition to an exponential law then occurs. For practical purposes, however, it may be considered that the metal always carries at least a very thin air-formed film so that the logarithmic growth is of little practical importance.

On exposing the metal with the thin air-formed film to a more corrosive environment the film is usually built up until protection adequate for that environment is attained. In the more severe conditions significant corrosion may occur during this process before protection is achieved, while in extreme cases, as for example in strong hydrochloric acid, the alumina is soluble and no film formation is possible. In almost all cases where film formation is posible, however, the exponential law applies. Under some conditions, and especially with pure aluminium, there may be an initial induction period during which the corrosion rate $\frac{dy}{dt}$ increases as corrosion proceeds, according to the equation

$$\frac{dy}{dt} = \beta + \alpha y$$

where "y" is the corrosion or film formation which has occurred up to the time "t", and β, the initial corrosion rate, is usually negligible. For the main part of the curve which follows this induction period, however, the corrosion rate decreases according to the equation

$$\frac{dy}{dt} = \beta - \alpha y$$

integration of which gives the exponential law:—

$$y = y_\infty \left[1 - e^{-\alpha(t - t_0)} \right]$$

The exceptions to this law occur (a) in the initial logarithmic growth, (b) in very severe conditions where film formation is impossible and (c) when the corrosion is accelerated by stress due to free loading. The latter phenomenon very rarely occurs in service,

but laboratory experiments indicate that when it does occur the corrosion rate accelerates immediately before failure.

If these three exceptions are ignored as being of limited practical importance the following conclusions may be drawn with regard to aluminium and its alloys.

1. Corrosion observed in the early stages of exposure under severe conditions may give an unduly pessimistic impression of the probable useful life of the metal unless the decrease and eventual cessation of corrosion is borne in mind.

2. Exposure of test specimens for a single period of arbitrary duration is of little use for predicting behaviour in service.

3. Provided that specimens are withdrawn at suitable intervals, the precise knowledge of the form of the corrosion-time curve allows extrapolation from results obtained in relatively short times. It is considered that this is usually a much more reliable method of expediting results than the acceleration of the actual corrosion process by artificial means which is often adopted.

The author is indebted to the British Aluminium Co. Ltd. for permission to publish this Paper.

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TECHNICAL PAPERS PROCEDURE

All papers submitted for publication in CORROSION are reviewed by the Editorial Review Committee, or specialists selected by that committee to review the papers. Suggestions of reviewers as to desirable additions or revisions are submitted to the author, who is given the opportunity to make the suggested changes. The paper in final form is accepted or rejected according to the judgment of the committee and the Editor of CORROSION. When the author can substantiate his viewpoint and prefers not to follow the suggestions of the reviewer and the overall paper merits publication, the author's wishes are followed.

Combatting Corrosion with Rubber Lining

*By R. McFARLAND**

The phenomena of corrosive attack and disintegration on rubber linings are similar to phenomena that occur with metals in contact with corrosive fluids. Many alloys are corrosion resistant as a result of films which form and make them passive. In some corrosive services, rubber linings exhibit the same ability to form passive or inert films, which limit further absorption and chemical attack on the rubber material beneath this inert surface layer. Rubber compositions in long contact with concentrated hydrochloric acid will develop a rubber hydrochloride film, which film is more inert than the parent compound and markedly lowers any further absorption and attack of the hydrochloric acid on the rubber compound. Solutions of chlorine in water appear to cause the same phenomena, forming a protective surface hardened against active attack of the rubber composition, by which the rate of attack is lowered greatly.

Rubber linings and alloys are similar in their behavior towards solutions which actively disintegrate them. For example, concentrated nitric acid will rapidly destroy brasses and copper-nickel alloys, and the same degree of attack occurs when rubber linings are in contact with concentrated or dilute nitric acid—the rubber hydrocarbon is destroyed and the inert fillers are loosened and washed away, until the entire thickness of rubber lining is restroyed. Powerful oxidizing agents, such as nitric and chromic acid, will attack rubber linings to produce a powdery oxidation product which, with the inert filler, will form a spongy skeletal structure.

In some services, alloys are protected by mechanical films that have deposited from solution. The film effectively covers the metallic surface and prevents corrosion. Such films also give additional protection to rubber-lined equipment in those services where films may be formed. In high concentrations of calcium hypochlorite, with excess chlorine, there will be deposited on the rubber-lined surface, a mechanical film of insoluble calcium salts which in itself assists in protecting the rubber lining and increases service life, enhancing the excellent resistance of the rubber lining to this service.

Fortunately, rubber linings are not susceptible to galvanic corrosion, concentration or areation corrosion cells, etc. An increase in temperature, or surface speed of the solution, within limits that normally would increase corrosion on metallic alloys that might be used in their stead, does not produce a proportionate increase in attack on rubber linings.

Failure of acid-resisting rubber lining due to the abrasive action of slurry passing through the valve.

However, rubber linings are susceptible to continual absorption and swelling in border-line service application. All rubber linings will absorb the fluid with which they are in contact and this absorption tends venetually to reach an equilibrium, in the case of those fluids that do not chemically attack the rubber by hydrocarbons and the hard rubber mixture. The writer has examined samples of rubber linings which have been in long contact with concentrated alum solution containing gentian violet as a coloring agent. At the end of four years' exposure at room temperature, the solution had penetrated the 3/16-inch rubber lining to a depth of 5/64-inch. When the specimens were examined under the microscope, the colored absorbed layer showed no ill effects and there was a clear line of demarcation between the absorbed layer and the remaining thickness of parent material.

In applying rubber lining for corrosion resistance, the standard commercial practice is to apply a minimum of ⅛-inch to 3/16-inch over the metal surface. Where chemical attack is expected, and in the case of soft rubber linings for combined corrosion and abrasion resistance, the thickness is increased to ¼-inch minimum. It is not safe practice to go below this recommended thickness and particularly so when softer synthetic rubber linings are used, such as Neoprene, Hycar and butyl. The softer the lining material, the more allowance should be made for increased thickness, because of the fact the softer material permits increased absorption and at an

* Technical Director, Hills-McCanna Co., Chicago, Ill.

increased rate when in contact with corrosive solutions.

Corrosion-resistant rubber linings are divided into three physical classes, namely, soft linings, semi-flexible linings, and the hard (Ebonite) linings. Soft rubber linings are homogeneous and of soft, resilient construction and are used for abrasion resistance and/or mild corrosion. The semi-flexible type of lining consists of a thin, soft layer of tie-gum between the metal surface, and the thick layer of specially compounded, semi-flexible "hard" rubber lining. True "Ebonite" lining contains the highest ratio of rubber hydrocarbon and sulphur, which when cured forms a highly inert, hard, chemically-resistant material. "Ebonite" is applied in sheet form to the metal surface and cemented in place, in the same manner as are the soft rubber linings and the semi-flexible type lining. The rubber-lined equipment then is placed in a vulcanizer of sufficient capacity and the whole cured under steam pressure. For repairs or assembly of lined equipment in the field, low pressure steam or infra-red heating is applied locally to the seams or patches to produce a homogeneous layer of chemically resistant rubber lining.

The design of the equipment to be rubber-lined has a bearing on the type and hardness of lining to be applied. The use of Ebonite is many times contraindicated or restricted on large expanses of metallic surfaces, because mechanical and temperature strains may cause the lining to chip, crack and fail in service.

The Ebonite type of materials are more satisfactorily applied to smaller pieces of equipment, such as pipe spools, tees, valves, elbows, etc., where proper support can compensate for mechanical and temperature strains.

There is no single type of rubber lining suitable for all types of chemical service. Where some semi-flexible and Ebonite types are used for general service applications many installations require that the rubber lining be compounded specifically for resistance to the service. Examples of such services are those involving hydrofluoric acid, sodium hypochlorite, wet chlorine, special plating solutions, photographic chemicals, etc. The rubber lining must be compounded specifically for resistance to the particular dissolved material, as well as for resistance to oxidation, diffusion, and absorption. Where discoloration or contamination is a problem, the linings must be specially prepared for such services. A rubber lining installation will give satisfaction only when the rubber manufacturer has been given detailed service information, so the proper type of linings can be compounded and applied.

Dissolved or entrained organic materials usually require a special rubber lining compound to resist deterioration and selective absorption of the organic material present in the solution, or their presence may eliminate rubber linings from consideration. With specially compounded rubber linings, swelling and deterioration usually is small with saturated hydrocarbons, hydro-aromatic hydrocarbons and heterocylics, whereas swelling and deterioration is high in aromatic hydrocarbons, halogenated hydrocarbons and carbon-sulfur compounds such as carbon disulfide and Thiopene. Swelling is small or negligible with polar type compounds.

Elevated temperatures in conjunction with the above classes of material always will cause increased swelling and will markedly accelerate deterioration. In cases where a rubber lining would have nominal resistance to these swelling agents, the fact must be taken into consideration that the rubber lining will undergo accumulative and selective absorption with the swelling agent to which it is least resistant and the resulting deterioration may be quite pronounced.

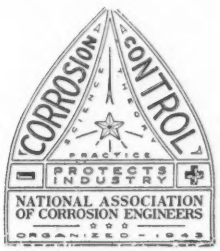
On the other hand, by using the proper type of rubber compound for this service, excellent life can be procured. In handling rayon spin bath solution containing small amounts of entrained carbon disulfide, years of service life can be secured from rubber lined equipment with specially compounded, semi-flexible or Ebonite-type linings. Through compounding, the deterioration and selective absorption of carbon disulfide is held to a minimum and satisfactory performance can be obtained in contact with this highly corrosive acid solution.

Where abrasion-resistance and corrosion resistance are encountered together it also is necessary to select rubber linings with utmost care. The illustration shows a semi-flexible type of acid-resisting rubber lining which failed from the abrasive action of the slurry passing through the valve. This abrasive action has removed most of the rubber lining on the upstream side of the valve body in those areas that have had to absorb the abrasion and impact of the suspended material.

This valve body was used in acid, raw cane sugar liquor service, pH 3.5, with the temperature at 140° F. The cane sugar liquor contained abrasive cellulosic particles torn loose from the cane structure in pressing to produce juice liquor. Also present was a considerable amount of dirt and grit carried along with the sugar cane stock from the harvesting fields.

This particular valve body was in continuous service for 900 hours, by which time the abrasive fibers and grit had completely worn away the acid-resisting, semi-flexible type valve lining.

This problem was solved by utilizing a special, soft-rubber type lining, which not only resisted the abrasive action of the fibers and grit, but also corrosion and deterioration from the organic acids present in the cane juice. The mating portion of this valve, the diaphragm closure, also was constructed of a similar, soft, abrasion-resisting rubber base material.



NACE News

NACE Directors' Meeting Is Held

Houston Section NACE heard M. B. Rossa, of the Parker Rust Proof Company, Detroit, Mich., give a paper on phosphate coatings at the regular January 18 meeting of the section at College Inn, Houston, Texas. Ninety-six members and guests were present.

Candidates for 1949 officers were nominated as follows: Jack L. Battle, Humble Oil & Refining Co., and Oliver Osborn, Dow Chemical Company, both of Freeport, for chairman; E. P. Doremus, Cathodic Protection Service, and A. L. Stegner, Tennessee Gas Transmission Co., both of Houston, for vice-chairman; Perry P. Spafford, Stanolind Oil & Gas Co., and M. A. Parr, Parkerizing, Inc., both of Houston, for secretary-treasurer; Roy V. Comeaux, Humble Oil & Refining Co., Baytown, and H. E. Waldrip, Gulf Oil Corp., Houston, for counselor; T. F. P. Kelly, James E. Mayor Co., and Lyle R. Sheppard, Shell Pipe Line Company, both of Houston, for trustee.

Corrosion problems in salt water disposal systems is scheduled as the topic of discussion at the February 15 meeting at the Alabama Cafeteria, Houston, Texas.

Metropolitan New York Section has scheduled a meeting March 10 at the Building Trades Employers' Association, 2 Park Ave., New York, N. Y., at which Dr. Harold A. Robinson, of Dow Chemical Co., Midland, Mich., is scheduled to speak on "Some Observations on the Cathodic Protection of Steel and Galvanized Iron." Metropolitan Section of the Electrochemical Society, Inc., will meet jointly with the section. Dinner will be served at 6:30 p.m. Floor discussion following the talk is invited.

Elementary Theories of corrosion with some practical examples illustrating these theories is the scheduled topic of a talk by William F. Gross of the Tretolite Company at the regular meeting February 21 of the Greater St. Louis Section NACE at the York Hotel, St. Louis.

The January 24 meeting was featured by an interesting illustrated talk by Walter Meyer of Nooter Boiler Works on the subject of metallizing, on which Mr. Meyer is recognized as a national authority. About 40 members and guests were present, a record attendance to date. A lively discussion on preparation of metal surfaces for organic protective coatings followed Mr. Meyer's talk.

NACE MEMBERS

IF You Change Addresses
IF You Change Company Affiliation
IF You Change Positions

Please notify the Central Office NACE, 905 Southern Standard Bldg., Houston 2, Texas, so that you will get CORROSION without delay and that association records can be kept abreast of your progress.

THANKS!

Officers and Directors Nominations Are Made

Officers and directors to fill 1949 posts were nominated at the meeting of the NACE board of directors in Cincinnati, Ohio, January 13-14, 1949. In accordance with the articles of organization and by-laws the following were nominated to fill the six positions to be vacated after the annual conference and exhibition:

For President—R. B. Mears, Carnegie-Illinois Steel Corp., Pittsburgh, Pennsylvania.

For Vice President—Vance M. Jenkins, Union Oil Co. of Cal., Wilmington, Cal.

For Treasurer—O. C. Mudd, Shell Pipe Line Corp., Houston, Texas.

For Director — 3 Year Term — Representing Active Membership—P. W. Bachman, Commercial Solvents Corp., Terre Haute, Indiana.

For Director — 3 Year Term — Representing Associate Members—E. D. Verink, Jr., Aluminum Company of America, New Kensington, Pennsylvania.

For Director — 3 Year Term — Representing Corporate Members—D. C. Glass, Pure Transportation Company, Chicago, Illinois.

F. L. LaQue, president of the National Association of Corrosion Engineers, said at the January 13 and 14 meeting of the board of directors in Cincinnati that he was satisfied with the financial status of the association, the progress made during the year in securing new members and on other matters.

A full agenda was presented to the board at the opening of the meeting. Among the significant items discussed were:

Refunds to Local Sections—This topic was discussed at length. Mr. Mudd pointed to the $50-per-region fund to be used in the development of new sections and added that in the event a region exhausted this amount it could be supplemented. A difficult problem in connection with the proposed refund system would be the setting of sectional boundaries and an accurate method of accounting.

Motion Pictures—Five motion pictures have been promised and arrangements made for presenting them twice daily at the exhibit. They will be shown in the Julep Room on the third floor of the Netherland Plaza.

Abstract Publication—Dr. Ivy Parker, chairman of the publications committee, expressed the belief 1946 abstracts can be published before the end of summer this year.

Changes in Articles—Consideration of changes in the articles and by-laws of the association occupied more time than any other item on the agenda. Among significant actions was a decision to consolidate the former "Corporate" and "Associate" member categories into one and call it "Corporate."

Appreciation Certificate—It was agreed that a certificate of appreciation will be presented at each annual conference to the outgoing president and that such certificates will be given all past presidents as well.

NACE MEMBERS IN ARREARS ATTENTION!

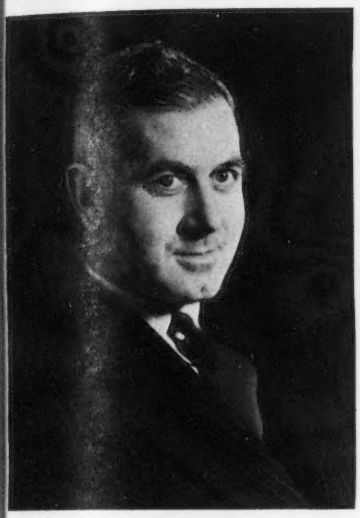
By-Laws of the National Association of Corrosion Engineers, Article I—Admission and Expulsion—Section 2, says:

"No member whose dues are in arrears for three months shall receive the publications of the Association until such arrears are paid."

Because of auditing requirements with which the magazine must comply, CORROSION cannot be sent to those whose dues for 1949 are not paid by April 1.

NACE Award Recipients Are Named

LaQue Is Given Whitney Award



F. L. LaQUE

Mr. LaQue is president of the National Association of Corrosion Engineers and previously has been a member of the executive committee and the board of directors and was vice president in 1947. He has consistently devoted a good deal of his time and energy to the affairs of the association, besides being active in several other scientific and technical societies.

He is in charge of the Corrosion Engineering Section, Development and Research Division, International Nickel Company, Inc., New York City. Since 1927, when he became associated with the development and research division of International Nickel, his principal activities have been in connection with the practical aspects of corrosion and the properties of corrosion-resistant metals and alloys.

He is a chemical and metallurgical engineering graduate of Queen's University, Kingston, Ontario.

Instrumental in founding the "Marine Testing Laboratory" at Kure Beach, N. C., he has been chairman of the Gibson Island Corrosion Conference of the American Association for the Advancement of Science and of the Coordinating Committee on Corrosion, besides activities related to corrosion in the American Chemical Society, American Society for Testing Materials, the American Society of Metals and the Electrochemical Society.

Approval of the recommendations of the NACE awards committee as to recipients of the 1949 Whitney and Speller awards was given at the January meeting of the association's board of directors in Cincinnati, Ohio. Chairman Walter F. Rogers of the awards committee advised the board that Dr. R. B. Mears, manager of the research laboratory of Carnegie-Illinois Steel Corp., Pittsburgh, Pa., had been named to receive the Whitney Award and that F. L. LaQue, of the International Nickel Co., Inc., New York City, had been named to receive the Speller Award.

Both recipients have been active as officers and members of the association. Mr. Rogers' letter announcing the decision of the committee pointed out that a canvass was made through Corrosion magazine of the members of the association and by letter to each corrosion worker not a member listed in the directory of the Inter-Corrosion Society.

The awards, named after Willis Rodney Whitney, who was first to receive the award in recognition of achievement in the field of corrosion science, and after Frank Newman Speller, first to receive the award in recognition of achievement in the field of engineering, are made annually to the persons voted best qualified in the two fields defined. The decision is made by a committee comprising at least six members, distributed geographically.

The awards committee for 1949, in addition to Mr. Rogers, of the Gulf Oil Corp., was composed of Dr. F. N. Speller, Pittsburgh, Pa.; Dr. A. Wachter, Shell Development Co., Emeryville, Calif.; Dr. H. J. McDonald, Loyola University, Chicago, Ill.; Dr. I. A. Denison, U. S. Bureau of Standards, Washington, D. C.; L. G. Vande Bogart, The Crane Co., Chicago, Ill.; J. C. Stirling, Stanolind Pipe Line Company, Tulsa, Okla.; Sam Tour, Sam Tour Co., New York City; Dr. T. J. McKenzie, American Cast Iron Pipe Co., Birmingham, Ala.; Dr. J. M. Pearson, Sun Physical Laboratory, Newton Square, Pa.

In 1948 the Whitney award was given to Ulick R. Evans, Reader of Science, Cambridge University, Cambridge, England, and the Speller award to John M. Pearson, director physical division, Research and Development Division, Sun Oil Co., Upland, Pa.

It is customary to make formal presentation of the awards to recipients during the annual conference of the association.

If past practice is followed during 1949, membership of the association will be asked to vote again on the recipients of the 1950 awards. Full information on which to base a recommendation will be made available at that time.

Mears to Receive Speller Award

DR. R. B. MEARS

Dr. Mears is manager of the research laboratory of the Carnegie-Illinois Steel Corporation in Pittsburgh, Pa.

He has been an active member of the executive committee and a director of the National Association of Corrosion Engineers. For the past three years he has been chairman of the Technical Practices Committee.

His professional career started on the technical staff of the Bell Telephone Laboratories in 1928. In 1932 he left this work to continue his education in corrosion under Dr. U. R. Evans at Cambridge University as a Carnegie scholar of the British Iron and Steel Institute. After receiving his doctor's degree from Cambridge in 1935 he became chief of the chemistry-metallurgy division of the Aluminum Research Laboratory and subsequently shifted to the development division of the Aluminum Company of America.

In 1946 he became associated with the United States Steel Corporation at its research laboratory at Kearney, N. J., and early in 1947 took his present position with Carnegie-Illinois.

Dr. Mears has made many major contributions to the basic knowledge of corrosion and its control and is the author of numerous papers in this field. He has served in official capacities and is a member of several technical societies.

Corrosion Problems

No. 14—The "Langlier Index" is used as an index of the corrosivity of natural or treated waters at normal temperatures. What is the effect of increasing temperature on the reliability of this index? Can the Langlier Index be used to indicate the probable corrosivity of domestic hot water (above 140° F.) with particular reference to galvanized storage tanks and/or copper tubes in indirect hot water heaters?

No. 15—Strong sulfuric acid can be handled in iron and steel equipment in concentrations ranging from 100% down to approximately 80%. Below that concentration the acid becomes progressively more corrosive to ferrous materials. Experience indicates that recovered acid at concentrations as low as 50-50%, as encountered in the petroleum and petro-chemical industries, is substantially non-corrosive to carbon steel and cast iron. It is assumed that this behavior is due to the presence in these recovered acids of substantial amounts of organic matter which is capable of acting as an oxygen consumer and/or corrosion inhibitor.

(A) What are the limiting concentrations and temperatures between which iron and steel can be used with those recovered acids?

(B) Is organic matter per se responsible or is the character of the organic matter critical? In other words, do the recovered acids from different industries in this general group behave differently?

(C) Are the special austenitic Cr-Ni alloys which are proving so useful in the handling of **commercial** sulfuric acid equally useful with these **recovered** acids, or does the organic material tend to render these materials "active" in contact with concentrations with which they would normally be "passive?"

No. 16—What is the effect of nickel content in 18-8 Mo (Type 316, 317, etc.) stainless steels on the ability of those steels to resist corrosion by sulfite liquors and vapors in paper mill service? Is the effect of nickel content equally apparent in cast and wrought materials of approximately the same composition? Is the effect of nickel content—if any—equally apparent in all sulfite mills, or do variations in the wood being processed or in the water used for make-up purposes effect the behaviour of the stainless steels?

Editor's Note: Consideration of the above question should take note of the fact that variations in nickel content may be accompanied by the variations in the content of chromium and/or molybdenum, in which cases accompanying variations in corrosion resistance may not be due to nickel content alone. See Question No. 9 (February, 1949).

No. 17—What materials are used for gate valves in handling raw and treated sanitary sewage and what is the service life of these gate valves?

No. 18—Is there any serious acceleration of corrosion when coupled galvanized and stainless steel sheets are exposed in the atmosphere? Is the trend in the same direction in all types of atmosphere; e.g., urban, industrial, marine?

Questions and Answers for this section should be submitted to L. G. Vande Bogart, Crane Co., Engineering and Research Division, 836 S. Michigan Ave., Chicago, Illinois. All questions will become property of NACE. Those not printed will be answered by mail. Questions should carry sufficient detail to describe the problem. Answers to printed questions are solicited. Authors of questions will remain anonymous to readers, while authors of answers may remain anonymous by request.

ANSWERS

No. 2 (January, 1949)—Air has access to the pipe when it is not full of boiler water. Probably corrosion is due to a *slow* leak in the valve which causes the blow down pipe to be kept warm, wet and aerated. When pipe is full of treated and non-corrosive water, air would be excluded and no corrosion would be expected.—F. N. Speller.

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No. 3 (January, 1949)—No, unless a galvanic cell is present somewhere in the line. In the event galvanic action is present and the iron pipe is anodic, noticeable galvanic action will occur at any break in the protective coating and accelerated corrosion can be expected.

—Anonymous

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Accelerated corrosion should be expected at breaks in organic coatings and is caused by either one or both of the following two mechanisms:

1) galvanic corrosion, and

2) concentration cell corrosion.

The probability of galvanic corrosion is discussed in an article entitled "The Effectiveness of Paint in Suppressing Galvanic Corrosion" in *Corrosion* 2, 67-77 (1946) June. This pointed out the dangers of coating imperfectly anodic members of structures immersed in sea water and would apply to the case of coated steel pipe coupled to copper or other more noble metals.

Accelerated corrosion at breaks in an organic coating could be caused also by the second mechanism, concentration cell corrosion. For example, if coated steel pipe is exposed to salt water, there will be a concentration gradient between the bare areas and the metal under the coating. This would make the bare areas anodic with respect to the coated areas. Because of this, accelerated corrosion would occur. However, the degree of corrosion may not necessarily be severe. If the break is small and if insoluble corrosion products are found at the break, corrosion products plugging the break.—G. W. Seagren.

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FINAL ANSWERS

No. 5 (January, 1949)—What are the qualifications a metal should have in order for it to be a satisfactory galvanic anode?

First, the galvanic anode must be definitely anodic to the metal being protected, usually iron or steel; second, current must also be supplied to the steel as a consequence of some reaction at the anode, usually its dissolution. From the standpoint of engineering practicability and economics, the list of suitable metals is limited to magnesium, aluminum and zinc. The standard electrode potentials, in volts, of the materials involved are: Mg,—2.3; Al,—1.7; Zn,—0.76; Fe (to Fe^{++}),—0.44. While it is unlikely that these potentials would obtain in any environment, they do indicate the native or inherent behavior of the metals. Any of the three metals with potentials above Fe would protect it in some specific environment. Magnesium and aluminum have the following theoretical advantages over zinc: they stand higher in the table of standard electrode potentials; they have lower electrochemical equivalents than zinc, e.g., if we assume 100 per cent current efficiency, a considerably smaller weight of magnesium or aluminum would be consumed than zinc per, say, one ampere hour of current supplied. The ampere hours supplied per pound of pure metal are given approximately by the figures: Mg, 997; Al, 1352; and Zn, 372.

—H. J. McDonald.

TO READERS OF "CORROSION PROBLEMS"

Initial response indicates the new feature "CORROSION PROBLEMS" is going to be both popular and of considerable practical value. Its continued success, however, depends on continued cooperation by readers.

Question are needed. No limit is fixed on the number that may be asked at one time. Illustrations and drawings may be included if their presence clarifies the question and makes them more interesting.

Answers are as necessary as questions. Contributions of information in answer to a published question, or opinions in disagreement with or supplementary to published answers are welcomed. "Corrosion Problems" is a potential open forum for CORROSION readers. Make use of it.

Pittsburgh Cathodic Protection Symposium Book Being Printed

Publication of a book made up of papers presented at the Joint Symposium on Cathodic Protection sponsored by the Electrochemical Society and National Association of Corrosion Engineers at Pittsburgh, Pa., December 8-10, 1947, now is under way. The book, comprising 23 articles, will total about 224 pages. A joint effort of the two sponsoring organizations, it will be sold through the National Association of Corrosion Engineers from its central offices, 905 Southern Standard Building, Houston 2, Texas.

Those found in preliminary circularizing to be interested in securing a copy, and whose names are on file in the NACE office, will be notified by mail when the volume becomes available for delivery. Others interested may reserve a copy by application to the NACE central office.

A selection of titles at random from among the articles included shows the subject has been covered in detail. Some of the titles are:

"Characteristics of Half-Cells as Reference Electrodes," by Paul Fugassi; "Coordination of Cathodic Protection Installations to Avoid Interference with Adjacent Structures," by L. B. Nelson; "Relative Merits of Various Cathodic Protection Current Sources," by G. R. Olson and G. W. Evans; "Anodic Behavior of Zinc and Aluminum-Zinc Alloys in Sea Water," by Thomas F. May, George S. Gordon and S. Schuldiner; "Cathodic Protection in the Control of Stress Corrosion Cracking," by Hugh J. McDonald and James T. Waber.

Price of the completed, cloth bound book, with 8½ x 11 inch pages, will be $6.00 a copy to NACE members and the Electrochemical Society members and $8.00 a copy to non-members.

A meeting of the board of trustees of the South Central Region was held in Houston January 28, 1949, with the following trustees present: Nathan Schofer, chairman; A. L. Stegner, L. F. Scherer, T. R. Statham and M. C. Fleming. Others attending were A. B. Campbell, T. P. Kelly, O. C. Mudd and G. R. Olson.

Dallas was selected for the 1949 annual meeting which will be held at the Adolphus Hotel October 3 and 4. Eight or nine technical papers will be presented in addition to a panel session with L. F. Scherer as group leader. A cocktail hour followed by a buffet supper will be arranged on Monday evening, October 3.

Committee appointments for this meeting were as follows: G. R. Olson, general chairman; T. R. Statham, chairman of local arrangements; R. A. Brannon, chairman of technical programs.

Other problems discussed at the trustees' meeting were the organization of local sections at Beaumont, Port Arthur, Orange, Lake Charles and in West Texas. Preliminary plans also were discussed for a short course on corrosion at the University of Texas.

Northeast Region's board of trustees held its regular meeting January 21 at 4 Irving Place, N.Y.C. Items on the agenda included: A report on the subjects discussed at the national directors' meeting in Cincinnati January 13 and 14 by Mr. E. P. Noppel; comments on the reasons for the change in size of the magazine CORROSION, discussions of proposed changes in rules of organization, and on the question of financing sections.

Mr. Noppel also reported the 1950 meeting probably will be held in St. Louis and in 1951 in a midwest city.

Plans for the year include two joint section-region meetings, one in the spring and another in the fall; formation of operating sections at Pittsburgh and Baltimore and possibly at Boston. Plans on building membership are to be defined at the next meeting, scheduled February 24.

Philadelphia Section has scheduled a meeting March 7 beginning with dinner at 6:30 p.m. at the Poor Richard Club, 1319 Locust Street, Philadelphia. A business meeting will start at 7:30 p.m. and an organized discussion on the following topics is to follow:

Preparation of Surfaces for Application of Organic Coatings; Protection of Sacrificial Anodes, Materials of Construction for Handling of Dilute Hydrochloric Acid, Addition of Wetting Agents to Improve Effectiveness of Inhibitors and Alloy Clad Metals vs. Solid Alloys.

Members are urged to bring guests.

Regular meetings of the section also are scheduled for June, September and December. H. F. McConomy, program chairman, welcomes suggestions from members for programs during the remainder of the year.

Corpus Christi Section made plans for eleven meetings during 1949 at its regular January dinner session at the Princess Louise Hotel, Corpus Christi, on January 27. Elbert D. Rankin, secretary-treasurer, reported a tentative program for the year as follows:

Four meetings with outside speakers.

Four meetings with local speakers on corrosion.

Two meetings of sectionalized discussions.

One meeting for a picnic.

Committees were appointed.

A permanent display of corrosion materials was begun. Wayne E. Broyles attended the meeting as a guest and permitted the display of his Multi-Combination Meter made by the M. C. Miller Co. Mr. Broyles also gave a number of interesting items for the exhibit table and has promised others for addition to the collection.

Gordon Conference Program Is Outlined

Formal program for the series of discussions to be held during the American Association for the Advancement of Science Gordon Research Conference, July 25-29, 1949, has been released by Harry R. Copson, chairman.

A letter addressed to those who attended the 1947 and 1948 conferences points out the meeting this year will be devoted to discussion groups, and that discussion leaders will prepare 20-minute summaries of the present status of their subjects, to be followed by invited discussions and finally thrown open to discussions from the floor.

Persons interested in the conference are invited to submit immediately lists of questions pertinent to the nine subjects programmed. Final lists of questions will be distributed to those indicating their intention to attend the conference.

The program is as follows:

July 25—H. H. Uhlig, "Theoretical Considerations Pertinent to Localized Corrosion." Norman Hackerman, "Effect of Condition of the Metal Surface on Localized Corrosion."

July 26—F. L. LaQue, "Pitting in Sea Water and Brines." W. Lynes, "Impingement Attack."

July 27—E. P. Partridge, "Pitting in Boiler Waters and Fresh Waters." A. Wachter, "Effects of Inhibitors on Localized Corrosion."

July 28—A. Brenner, "Pitting Through Coatings." R. B. Mears, "Granular, Transgranular and Intergranular Corrosion."

July 29—F. W. Fink, "Techniques for Studying Localized Corrosion."

Salt Water disposal and the corrosion problems related to it was the topic of a series of short talks by engineers at the Houston Section NACE dinner meeting at the Alabama Cafeteria on the night of February 15.

Eighteen Wrought iron shields are being installed on the Long Island Railroad's wooden trestle across Jamaica Bay as fire breaks. Each shield consists of two curtains fixed to trestle about 40 feet apart.

Merger of Alabama Gas Co. and Birmingham Gas Co., of Birmingham, Ala., into the Alabama Gas Corporation has been announced.

"Chemistry and Industry," a review published in France, is being received by Central NACE office in exchange for CORROSION.

Corrosion Engineering Short Course Planned

Book Reviews

AQUAMETRY—APPLICATION OF THE KARL FISCHER REAGENT TO QUANTITATIVE ANALYSES INVOLVING WATER, by John Mitchell, Jr., and Donald Milton Smith. Interscience Publishers, Inc., New York and London—444 pages, $8.00.

"Aquametry," a term coined by the authors, is the analytical process of water measurement which has become an important phase of analytical chemistry in evaluating practically all types of materials.

Emphasis has been placed on the application of the Karl Fischer reagent in quantitative water analyses, and one chapter is devoted to summarizing its application.

Analytical methods are explained for a wide variety of organic and inorganic compounds and reactions. One chapter is devoted to techniques of titration applicable to "aquametry." Procedures are described in sufficient detail for use as a laboratory manual.

The book is of value to the laboratory scientist or engineer who desires knowledge concerning the determination of the water content of various materials.

METALLIC CORROSION, PASSIVITY AND PROTECTION. (Second Edition). By Ulick R. Evans, M. A., Sc. D., Cambridge University, England. Published by Edward Arnold & Co., London; Longmans, Green & Co., New York. 863 pages. Index, $12.50.

The Second Edition of the middle member of the metallic corrosion triumvirate ("Corrosion—Causes and Prevention"—Speller; "Metallic Corrosion, Passivity and Protection"—Evans and "Corrosion Handbook"—Uhlig) has not suffered by revision. If the explanation and answer to any metallic corrosion problem cannot be found in the 460,000 word text, reference to the work of the 2865 authors quoted most certainly will give them.

The introduction is a short review of the principles of electrochemistry written in a manner the novice can understand.

The subjects in each chapter are treated from three viewpoints: a) scientific or theoretical; b) technical or practical; and c) quantitative or mathematical.

Dr. Evans gives detailed studies of film formations and their relation to corrosion and passivity. Corrosion involving high temperatures, the absorption of oxygen and the non-absorption of oxygen of both ferrous and nonferrous metals is covered fully. The influence of structure, stress and strain is discussed.

Corrosion mitigation or protection by inhibition, chemical treatment, paints, metallic coatings and cathodic protection is described in detail.

The chapter on corrosion testing methods gives proper means of testing and correctly interpreting the results.

The appendix, "Optical Methods for the Determination of Films on Metals Based on Polarization and Interference Phenomena," is written by Mr. A. B. Winterbottom.

Corrosion engineers in the petroleum industry will be particularly interested in the chapter on paints and enamels, and the discussion of failures due to hydrogen penetration.

Dr. Evans has shown by his continuous studies of metallic corrosion, as evidenced in this revision, that he still is blazing the trail in this field.—L.S.

COPPER AND COPPER-ALLOY SPECIFICATIONS INDEX. The American Brass Company, Waterbury 88, Connecticut. Publication B-34, Second Edition. No charge.

Revised edition of a book issued a year ago by this company as a time-saving convenience for those using standard specifications of engineering societies and government agencies. First section lists Anaconda's most generally used alloys, with applicable specifications. Second section lists specifications in numerical order with a brief description of materials covered as to grade, type, temper, anneal, etc. Side indexed.

CORROSION BY CONCENTRATION CELLS. Corrosion Engineering Service, The International Nickel Co., Inc., 67 Wall Street, New York 5, N. Y. No charge.

Reasons for galvanic cell corrosion and methods for helping to overcome it are covered in this publication. It gives engineering details, drawings and essential illustrative material. The brief but informative pamphlet is based on more than 40 years' study of this and other phases of corrosion.

Houston Symposium Slated On Conserving Resources

Engineers' Council of Houston, an organization composed of 18 associations of men in various fields of engineering, will hold its second annual symposium at the Rice Hotel, Saturday, April 2, it was announced by William F. Hull, publicity committee chairman. The symposium "Conservation of Our Natural Resources" will be featured by five talks, two each at morning and afternoon sessions and one at the night dinner session.

A tentative program has been released as follows:

Morning Program—"Conservation of Water," by Paul Weaver, president, American Association of Petroleum Geologists; "Conservation of Soil," Dr. W. A. Albrecht, chairman, Department of Soils, University of Missouri. Afternoon Program—"Conservation of Major Sources of Energy," by Eugene Ayres, Gulf Research and Development Co., Pittsburgh, Pa.; "Conservation of Character of Man," Dr. Sam L. Joekel, The Austin Presbyterian Seminary, Austin, Texas. Evening Program—"Conservation of Man, With Emphasis on Food," by Louis Bromfield, Malabar Farm, Lucas, Ohio.

Dean F. Saurenman, Baker Oil Tools, Inc., P. O. Box 3048, Houston 1, Texas, is head of the reservations committee.

Engineers and management specialists interested in attending a short course in corrosion engineering are invited to write Nathan Schofer, Cities Service Refining Corp., The Tutwiler Refinery, Lake Charles, La. Mr. Schofer is chairman of a committee named by the South Central Region NACE to get a consensus on the proposed course, and if sufficient interest is evidenced, make arrangements with a university engineering school to hold it this year. Letters expressing interest should define the specific aspect of corrosion in which the writer is interested, forecast the number likely to attend, the most suitable time it should be held, and give any other pertinent comments.

Initial consideration of the proposed course developed the idea it would be directed in general toward a review of fundamentals, rather than application. Areas under consideration include electrochemistry, corrosion fundamentals, cathodic protection, metallurgy and inhibition.

While specific organization has not been defined and will not be determined finally until expressions from those interested have been considered, plans include possible use of a series of lectures originally given at a short course on corrosion at the Stevens Institute of Technology and presentation of subjects by qualified specialists from industry, with or without supplementary assistance from the teaching staff of the university selected.

The one or two weeks' course may be attended by about 200, and fees covering cost of the program are contemplated.

Research Into methods of electroplating complex geometric shapes will be the subject of the American Electroplaters' Society's recently inaugurated research Project No. 11 on "Current and Metal Distribution in Electroplating," at Evansville College, Evansville, Indiana. Director of the project will be Dr. John Kronsbein, head of the college department of engineering. Dr. Kronsbein has done experimental work in this field previously.

Potential Accuracy of one part in a billion or even ten billion is a theoretical possibility of the atomic clock, controlled by a constant frequency derived from a microwave absorption line of ammonia gas, providing a time constancy of one part in ten million. Dr. Harold Lyons of the National Bureau of Standards microwave laboratory developed the new system of measurement which promises to surpass by one or two orders of magnitude the accuracy of the present primary standard, the rotating earth.

Deterioration Prevention Abstracts Offered by Research Council

Direct Readings of stress in electrodeposits is possible with a new instrument, the spiral contractometer, developed by Aber Brenner and Seymour Senderoff of the National Bureau of Standards. The instrument, said to be rugged and self-contained, requires no auxiliary apparatus and is well adapted to both industrial process control and laboratory research. Determination of excessive stress, usually the result of the chemical nature of the plating solution or impurities in the deposit, may cause peeling, blistering or cracking and thus render the base metal more susceptible to corrosion. It may also induce failures due to stress corrosion and usually tends to decrease fatigue resistance of the plated article.

Nickel Electroplating Discovery Is Revealed

A discovery the research committee of the American Electroplaters Society believes may well prove to be the cornerstone for improving the corrosion resistance of nickel electrodeposits was announced at the quarterly meeting of the society in Rockford, Ill., December 10, 1948.

The Research Directing Committee, chairman of which is W. M. Tucker of Eastman Kodak, reported porosity of electroplated nickel foil varies with the crystal structure of the deposit. Since it has been generally conceded that wrought foils are less porous than similar electrodeposited foils from commercial baths, this discovery may well prove to be the cornerstone for improving the corrosion resistance of nickel electrodeposits. Future researches on this subject will determine if nickel baths operating under commercial conditions can be modified to give a crystal structure with an improved corrosion resistance. Dr. N. Thon of Princeton University is conducting work on this project entitled "Nature and Effect of Porosity in Electrodeposits."

The research committee currently is conducting researches on eight other fundamental problems in electroplating in a number of leading universities and at the Bureau of Standards.

The National Research Council of the National Academy of Sciences (Prevention of Deterioration Center, Room 204), 2101 Constitution Avenue, Washington, D. C., offers the "Prevention of Deterioration Abstracts" on a yearly subscription basis. These abstracts are classified under the following headings: Biological Agents; Electrical and Electronic Equipment; Fungicides and Other Toxic Compounds; Lacquers, Paints and Varnishes; Leather; Lubricants; Metals; Miscellaneous; Optical Instruments and Photographic Equipment; Packaging and Storage; Plastics, Resins, Rubbers, and Waxes; Textiles and Cordage; Wood and Paper. Cross references are included in each issue; author and subject indexes are compiled at the conclusion of each volume. Material is obtained from journal articles, patents and unpublished reports from government, university, and industrial research groups here and abroad.

Approximately 2000 pages are published a year, in two volumes of six issues each. Individual abstracts are in loose leaf form so they may be arranged in any manner desired by the individual receiving them. Comments are added to many of the abstracts to correlate relevant information, to evaluate reports, or to make suggestions for further research.

The yearly subscription rate, which includes two binders and index guides, is currently $37.50. The rate will be $50.00 for requests reeceived after July 1, 1949. All subscriptions run from July 1st to June 30th. Back issues are available from April, 1946, when the series was started.

An "Advance List," a monthly bibliography of all the reports received in this field by the Prevention of Deterioration Center, is also available for an additional $10.00 per year.

TP-7 COMMITTEE

The correct name of the chairman of this committee, in which there were typographical errors in the February issue is as follows: M. A. Scheil, Director Metallurgical Research, A. O. Smith Corp., Milwaukee, Wis.

NEW CORPORATE AND ASSOCIATE MEMBERS

Following is a list of new Corporate and Associate members who have joined NACE during the period from January 15 to February 15, 1949, bringing to 264 the number of these types of sustaining Association memberships:

Pacific Pipeline and Engineers, Ltd., Montebello, Cal.	L. F. Dishman
Signal Oil and Gas Company, Los Angeles 14, Cal.	E. O. Kartinen
Plastic Coating Corporation, Houston, Texas	W. R. Walne
E. I. duPont de Nemours & Co., Wilmington, Del.	W. R. Myers
General American Transport Corp., Chicago, Ill.	Paul Maloney

Gas Technology Short Course Scheduled

The fourth annual short course in gas technology will be held at Texas College of Arts and Industries, Kingsville, Texas, May 30-June 1.

It is sponsored by the Southern Gas Association.

Besides attending lectures and assemblies, those attending will inspect industrial plants in the vicinity and visit the King Ranch.

Dr. Frank H. Dotterweich, director of the A. & I. engineering division, is chairman of the administrative committee. Working with him are Chester Young, Dallas, Lone Star Gas Co., chairman of the utilization section; D. T. McRoberts, Shreveport, United Gas Pipe Line Co., chairman of the production and transmission section; W. B. Wood, Brownsville, Rio Grande Valley Gas Co.; C. A. McKinney, Houston, United Gas Corp.; R. H. Ulrich, Birmingham, Southern Natural Gas Co.; W. C. McGee, Jr., Houston, Tennessee Gas Transmission Co.; George Elmer May, New Orleans, New Orleans Public Service; R. M. Hutchinson, Houston, Houston Natural Gas Corp.; W. H. Ligon, Nashville, president of the Southern Gas Association; and R. R. Suttle, Dallas, managing director of the association.

Western Region heard Dr. Richard Pomeroy of Montgomery and Pomeroy, Pasadena, California, speak on "Corrosion by Waters Containing Sulfides—Its Causes, Effects and Preventive Measures," at its February 9 meeting in the Roger Young Auditorium, Los Angeles, Cal.

Dr. Pomeroy, for eight years chemist for the Los Angeles County Sanitation District and for the past ten years consultant in chemical engineering, specializing in sanitation and sulfide problems in particular, is recognized as one of the leading authorities in this field in the West. His talk dealt with sulfide production, identification, prevention or removal in sewage works, water systems and soils. Slides and data accompanying the talk showed corrosion of plumbing and other metal and concrete structures in contact with sulfides, and the problems involved in minimizing its effects.

CORRECTION

North Central Region officers were inadvertently removed and officers of St. Louis Section put in their stead on the regional directory page of February CORROSION. Current officers are properly listed on the page in this issue. Apologies are extended to both the North Central Region and St. Louis Section officers for this error.

PERSONALS

W. R. Weischendorff has been named western district manager by The Dearborn Chemical Co., 310 S. Michigan Ave., Chicago, Ill., manufacturers of water treatment chemicals and No-Ox-Id rust preventives.

Raymond B. Seymour, formerly chief chemist for Atlas Mineral Products Company, has returned to the firm as executive vice president and general manager. Dr. Seymour formerly was associated with the development of several corrosion-resistant cements, linings and protective coatings now manufactured by the firm. He also has been with Goodyear Tire and Rubber Company as research chemist, Monsanto Chemical Company as group leader in plastics and research and director of the Industrial Research Institute of the University of Chattanooga.

Stephen Dudiak, Rutherford, N. J., has been named chairman of the board; Maxwell Sawyer, Mt. Vernon, N. Y., president, and Jack O'Hara of North Arlington, N. J., vice-president and secretary by Crowell Chemical Co., East Rutherford, N. J.

Ray H. Stuff has been named sales-manager of the Nox-Sound Division, Nox-Rust Chemical Corporation, 2429 S. Halstead Street, Chicago, Ill. Experienced in marketing, advertising and product control, he has held responsible positions with several major firms, most recently with the A. O. Smith Corp., Milwaukee.

Dr. Fred E. Kendall has been named vice-president, director of research and sales, International Rustproof Corp., Cleveland, Ohio.

Industrial Products sales division of the B. F. Goodrich Company has become the Industrial and General Products Division and now includes the Plastic Products Sales and Production departments, it was announced by James J. Newman, vice president. E. F. Tomlinson is division general manager. Clyde D. DeLong has been named manager of the Plastic Products Sales department which will be moved from Akron, Ohio, to the company's plastic products plant near Marietta, Ohio. Koroseal materials are the plant's principal output. R. L. Hill, R. R. Speicher and C. J. Mischler will handle industrial markets.

An Internal Curing insulating varnish which Irvington Varnish and Insulator Company, Irvington, N. J., claims produces bonding strengths approximately 25 percent greater than heretofore known has been announced. Known as Harvel 1012C, the varnish is said to be fast curing, oil-proof and with good resistance to chemicals and moisture.

NEW PRODUCTS

Materials – Service – Literature

Heat Exchanger Is Resistant to Corrosion

National Carbon Company's "Karbate" Impervious Graphite Heat Exchanger, Style FH, size 1½, is recommended for heating or cooling corrosive fluids, particularly in tanks with liquid depths up to 16 inches. It is designed for horizontal operation and consists of two "Karbate" impervious graphite tubes of 1½ in. I.D. x 2 in. O.D. in a parallel flow bank between "Karbate" headers. Connections for the heating or cooling medium are made with "Neoprene" "Flexlock" connectors.

"Karbate" Brand Impervious Graphite has properties of high thermal conductivity (three times as high as carbon steel) and resistance to the action of most acids, alkalis and other corrosive, solvent or reducing agents, and particularly to all concentrations of hydrochloric acid and nearly all concentrations of hot sulphuric, phosphoric and acetic acids, wet chlorine and the organic solvents, manufacturers say.

Recently announced also is National Carbon Company's "Karbate" seven-tube Impervious Graphite Shell and Tube Heat Exchanger, Series 70A, as a redesign of the previous Series 70. Basic elements of the new unit may be converted from a single pass to a double pass unit by a simple change of covers. The exchanger can better be adjusted to varying rates of flow and amounts of liquid handled. This feature gives the unit added utility without affecting its original efficiency.

Replacement of tubes may now be made quickly and easily in the field.

Both exchangers are manufactured by National Carbon Company, Inc., 30 East 42nd Street, New York 17, N. Y.

Nielco Laboratories, chemical and research engineers, Detroit, Mich., has issued a "Preliminary Technical Data Sheet" on its new type rust preventive coating and primer which is called "Niel-Coat" P-110. The technical data sheet says the new coating was designed for application over rusted metal to stop rusting and prevent further corrosive action. In "Piel-Coat" P-110, the material issued by the firm states, "phosphoric acid is tied in with oils and resins in minute uniform molecules that together form a stable emulsion in the presence of emulsifying agent that will not break down over a prolonged period of time. When this emulsion is applied over the rusted surface the acid reacts with the iron oxides and in doing so brings the oils in to form a tough and pliable protective coating capable of resisting atmospheric action as well as chemical action of acids, alkalies, brines and fumes."

A Chemical Dipping process by means of which aluminum surfaces are said to acquire added corrosion resistance is announced by the Colonial Alloys Co., Philadelphia. The process also is said to make an excellent paint base and render the aluminum smudge-proof.

A Rubber-Lined, straight line totally enclosed pickling and washing machine which prepares formed-metal products for enameling is described by B. F. Goodrich Company, Akron, Ohio, in a folder recently issued. Rubber lining is by the Vulcalock process. Elimination of odors, corrosive fumes, splashing and dripping are claimed, along with substantial man-hour and cycle-time reductions.

Hazards in Electrical systems due to heat, crystallization or deterioration due to various other causes are pointed out in an article entitled "Electrical Distribution Systems" in the January, 1949, issue of "The Condenser," a publication of the Mutual Boiler Insurance Company of Boston, Mass. Pictures showing various hazards resulting from deterioration of electrical systems accompany an article comparing current and obsolete wiring codes, and urging preventive maintenance as a means of avoiding similar hazards.

A Portable Hardness tester for Rockwell readings weighing only 3 pounds 6 ounces has been developed by the Riehle Testing Machine Division of American Machine and Metals, Inc., East Moline, Ill.

Koroseal Has been found a satisfactory substitute for cloth in the manufacture of stretchers designed for use in corrosive environments, or where mildew and mine damp are present, the B. F. Goodrich Company, Akron, Ohio, reports.

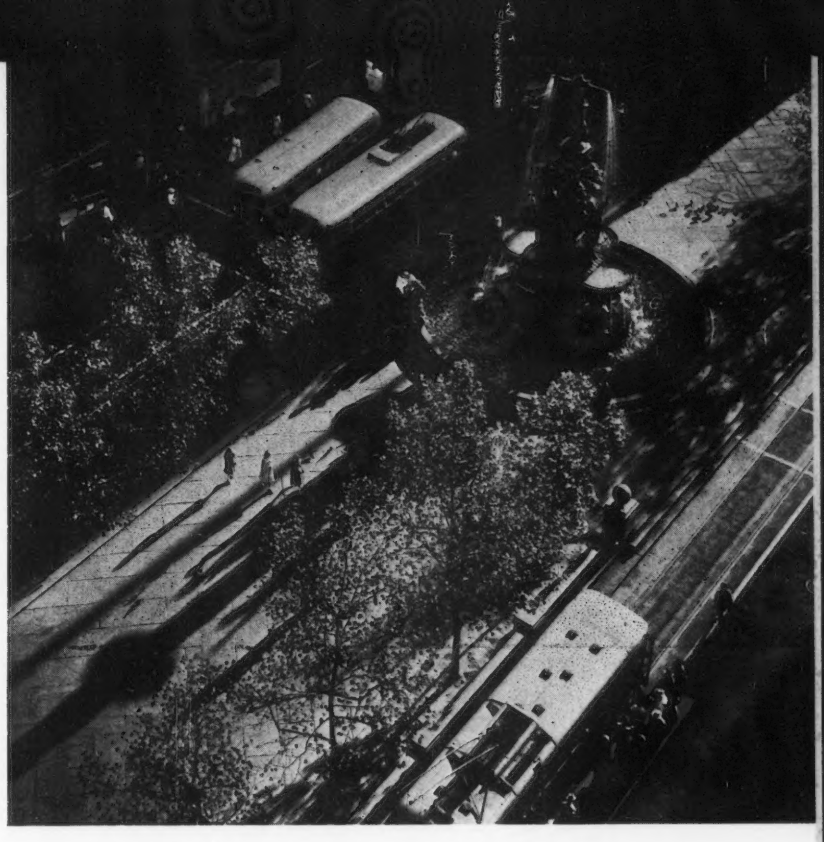
Ardun Company of Tulsa, Oklahoma, has been appointed distributor of Tube-Turn welding fittings and flanges, John G. Seiler, executive vice-president of the latter firm, has announced.

Lumarith X_F, a new flame and heat-resisting cellulose acetate thermoplastic material has been developed by the Celanese Corp. It has Underwriters' Laboratory approval for certain items including safety respirators and safety goggles.

Titanium Alloy Manufacturing Co., New York, and its plant at Niagara Falls have been taken over by National Lead Company.

A New Pipe joint which Gates Engineering Company, New Castle, Delaware, claims eliminates several expensive steps encountered in lined pipe installations is being manufactured in 1-2-inch to 4-inch pipe sizes as 45 degree ells, 90 degree ells, Y's, T's and flange kits. The Gaco joint eliminates welded fittings, detailed layout plans, and makes repairs by plant maintenance crews possible, the manufacturers claim.

Unification of Screw Thread Standards accord details are outlined in National Bureau of Standards Technical Report 1315.



This is Fountain Square, ringed by the tall temples of modern commerce. The fountain, constructed in 1871, was given by Henry Probasco to the city along with the land it occupies. The figures exemplify the gift of the waters.

CINCINNATI, OHIO

Where 1949 NACE Conference Will Be Held

COLUMBIA, Losantiville and North Bend, all located on land now within the confines of Cincinnati, originally were established in the 1780's as trading posts on the Ohio river. The advantages these early settlements enjoyed from the use of the river for travel and commerce have continued to the present day, with the modern city utilizing the 15,000-mile-long internal waterways system of the Ohio and the Mississippi system for trade and pleasure. The city also is centered in a network of seven trunk railroads which handle in excess of 1,500,000 carloads annually, and 20 major highways over which travel 128 interstate carrier lines.

Basically an industrial city with soap, machine tools, playing cards and electrotypes its leading products, Cincinnati nevertheless has achieved substantial prominence as a cultural center with a symphony orchestra of international reputation, an art academy and institute, and what is said to be the largest municipally-owned university in the United States.

Its 73.8 square miles covering rolling hills, the city has 128 parks covering 4061 acres.

Among colorful characters in its early history was Mad Anthony Wayne, a hero of the Revolutionary War, who arrived in 1793. Arthur St. Clair, governor of the Northwest Territory, was so bountifully entertained in 1789 by the residents of Losantiville he dubbed the city "Cincinnati" after the society founded by officers of the American Continental Armies.

Not all, however, were characters of such good repute. An occasional visitor during the lusty days when the city was the rendezvous for keelboaters, was the notorious Mike Fink, adept with a murderous weapon shaped in the form of a metal rake, one blow of which would maim or kill.

Its early population was well-leavened with Irish and Germans. In 1849, America's first "Sangerfest" was held, outgrowth of the traditional interest these races have in music. A good many who afterward became well-known in the arts have been born in or made this city their home.

CORROSION DAMAGE PREVENTION...

with Somastic ★

A Railhead Plant in the Field

By protecting pipe with Somastic Pipe Coating, corrosion can be prevented before it starts. Long range experience has demonstrated under severe conditions in highly corrosive locations for already known periods of 18 years that this impervious coating has proved the staying quality of its protection.

Authentic records established in the A.P.I. ten-year pipe coating tests and on thousands of miles of operating lines furnish conclusive evidence of this coating's effectiveness.

Somastic Pipe Coating is a special mixture of asphalt-mix mastic compounded to rigid specifications and firmly bonded to the pipe as a thick seamless coating. Overlapping field joints of the same mixture make this protection continuous along the pipe line.

SOMASTIC *PIPE COATING*
★ Reg. U. S. Patent Office

Manufactured by

BECHTEL CORPORATION
SAN FRANCISCO and WILMINGTON
California
— in the 11 Western States and in foreign countries

H. C. PRICE CO.
SOMASTIC DIVISION
BARTLESVILLE, Oklahoma
— in the 37 States east of the Rocky Mountains

Central Plant

Places to Go and Things to See . . .

Long known as a city of music and laughter, ever since the days before the turn of the century when Vine Street was a gay white way with over 200 drinking places in a two-mile stretch, Cincinnati still preserves its reputation for fine foods and entertainment. Many restaurants pride themselves on the excellence of their sauerbraten, potato pancakes, pigs knuckles and goulash and dumplings. The city's present places of amusement are both more decorous and more numerous, and the visitor will find a wide variety of sights and places from which to choose.

A few of the more prominent are listed herein:

PARKS

Eden Park—Krohn Conservatory. An unusual display of flowers and plants. Open daily 10 a.m. to 5 p.m.

Zoological Garden—Vine and Erkenbrecker Avenues. 9 a.m. until dark, open daily. Animals presented in facsimiles of their natural habitat.

MUSEUMS

Taft Museum—316 Pike Street. A fine example of Federal architecture built 125 years ago. It contains displays of paintings, Chinese porcelain and other art objects.

Museum of Natural History—Central Parkway at Walnut Street. Open daily except Sunday 9 a.m. to 5 p.m.

Cincinnati Art Museum — The Zoo-Eden street car line (Number 49), which can be caught on Fifth Street, is operated over the only inclined plane railway still operating in the city. The incline goes up the side of Mt. Adams along 945 feet of steep tracks, lifting the cars 270 feet.

Coney Island—The city's biggest entertainment plant a few miles up the Ohio River from the city. It can be reached by road but many prefer to take the Island Queen, the resort's river boat.

NIGHT CLUBS

Numerous night clubs may be found both in Cincinnati and on the Kentucky side of the river.

SCENIC DRIVES

Motorists can reach Kentucky by four bridges, all in the downtown area. Much scenery of natural beauty is located within a few miles on major, well-paved highways.

Mt. Airy Forest, on the northern edge of the city, includes 1345 acres with 25 miles of trails for hikers and horsemen.

PLACES OF INTEREST

The civic and publicity department of the Cincinnati Chamber of Commerce has supplied the following list of places of possible interest to visitors. Where tours are indicated it is suggested arrangements be made directly with the firm concerned.

Procter & Gamble—R. C. Jentz, office manager, Ivorydale, Cincinnati.

Fashion Frocks, Inc.—Mr. E. Dinan, 3301 Colerain Avenue, Cincinnati.

Sterling Glass Co.—1069 Celestial Street, Cincinnati.

Pallazzolo & Company, macaroni manufacturers—Peter Pallazzola, 2045 Gilbert Avenue.

Rookwood Pottery—Rookwood Place, Cincinnati.

University of Cincinnati—Said to be the nation's largest municipal university.

Carew Tower—Cincinnati's tallest building. Visitors may view Cincinnati and environs from the top for 50c. Open each day to 5:30 p.m.

Gruen Watch Company—Time Hill, Cincinnati.

Baldwin Piano Company—1801 Gilbert Avenue. No children under 12. Tours 9:30 to 11:30 and 2:30 to 4:30.

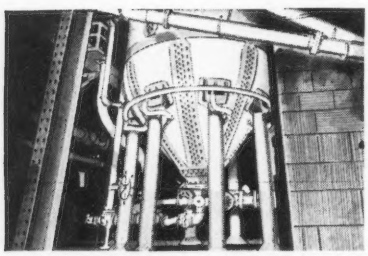
Formica Insulation Co.—4620 Spring Grove Avenue. Afternoon tours only for high school, college and engineering groups.

Cincinnati Milling Machine Co.—Marburg Avenue. Tours for factory and industrial organizations; contact Chas. M. Reesey, advertising manager.

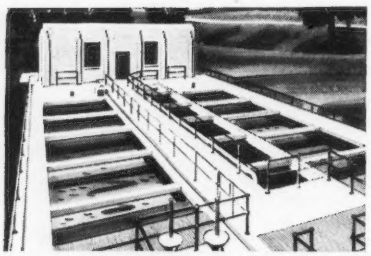
"The Electrochemical Behavior of Zinc and Steel in Aqueous Media," by R. S. Hoxeng, Case Institute of Technology, Cleveland, Ohio, a paper scheduled for presentation at the General Industry Symposium, is expected to prove of wide interest to those attending the conference. The subject now is being studied widely by many users of galvanized iron for resistance to waters.

New Advances In Licking Severe Corrosion

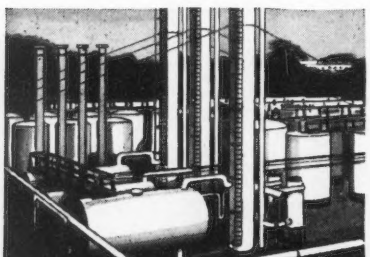
These 4 typical cases show you how, at last, corrosion problems which have defied solution are being licked with UCILON Protective Coatings!



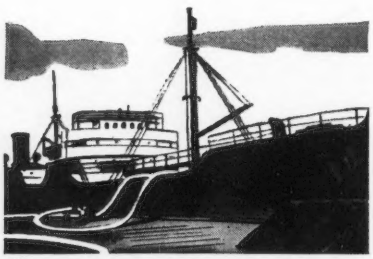
1. IN A PAPER MILL, conveyor pipe for sulphite paper pulp, containing 7% acid and 9% alum, was ordinarily corroded through in 2 months. Coated with Ucilon 400, the pipe lasted 7 to 10 months longer!



2. IN A SEWAGE DISPOSAL PLANT, Ucilon 400 was applied to sedimentation tanks, chlorination equipment, metal work submerged in wet sewage — and outlasted every other coating ever tried! 7 months on steel cover plates used as walks, for example, and no signs of wear!



3. IN A CHEMICAL PLANT, pipelines had to be protected against atmosphere laden with caustic fumes. No former coating lasted even 6 months. But Ucilon 400 was still going strong *22 months* after application!



4. IN AN OIL TANKER, Ucilon-coated panels in the hold were in contact with 100-octane gas, diesel oil, kerosene, salt water ballast. Ucilon 400 coatings were still good *after 10 months!* No previous coating survived even one cargo.

UCILON* 400

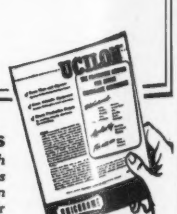
Ucilon 400 is a flexible, glossy, air-drying coating for metal, concrete and wood. It is applied by brushing or spraying. When solvents evaporate, a tough "plastic" film is formed. Ucilon 400 provides exceptional resistance to acids, alkalies, alcohols, oils and greases, salts, water, cleaning compounds, oxidizing agents.

OTHER UCILON COATINGS

Ucilon 1601—a ready-mixed, extra-bright aluminum paint with exceptional outdoor resistance. It stays bright under prolonged exposure, withstands elevated temperatures.

•

Ucilon 1501 — a very hard, chip-resistant baking coating which resists chemical attack at temperatures higher than recommended for Ucilon 400.



SEND FOR THIS BULLETIN *which gives more details on various Ucilon coatings and their properties.*

There you have four typical examples of the effectiveness of Ucilon coatings. Company after company, in many industries, have had similar experiences. Until Ucilon 400 was put on the job, they found no real solution to their tough corrosion problems, no end to excessive maintenance. So, if you are still seeking the answer to severe corrosion problems, we invite you with confidence to investigate and try Ucilon. We believe that you will tell us what many other users have—that Ucilon 400 resists *more* corrosives for *longer* periods than any other coating they ever tried. We'll gladly give you specific recommendations for your application. Write today.

*Trade Mark Reg. U. S. Pat. Off.

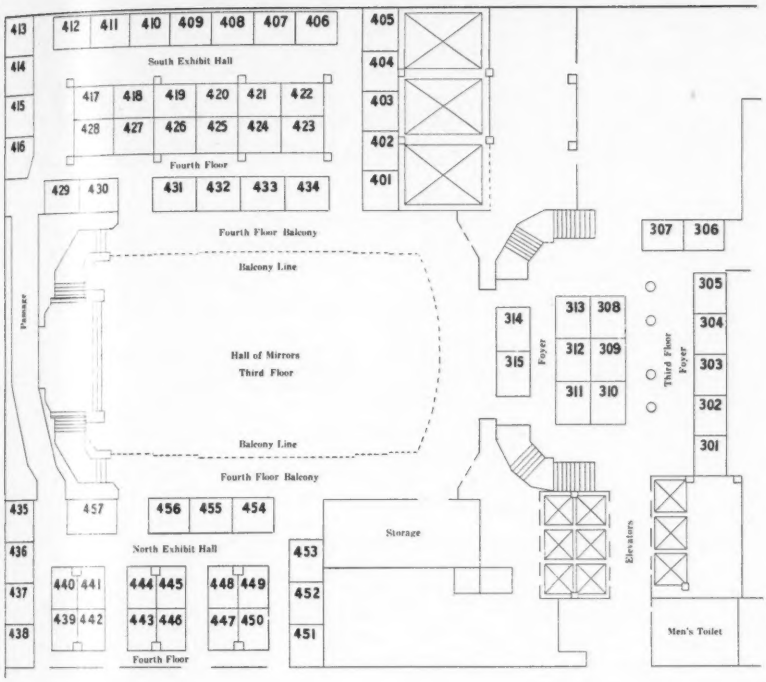
See our display at Booth 454 at exhibit of NACE (Netherland-Plaza Hotel, Cincinnati, April 11-14th)

UCILON Protective Coatings

UNICHROME **products of UNITED CHROMIUM, INCORPORATED**

51 East 42nd St., New York 17, N.Y. • Detroit 7, Mich. • Waterbury 90, Conn. • Chicago 4, Ill. • Dayton 2, Ohio • Los Angeles 13, Cal.

Conference Exhibitors Are Listed



Following is a list of the exhibitors at the 1949 Conference to be held in Cincinnati April 11-14. At the right of each name will be found the number of the booth to be occupied by the exhibitor and by reference to the diagram of the exhibit floor the location of the booth can be ascertained. The booths are numbered according to the floors of the Hotel Netherland Plaza on which they appear: Booths located on the third floor begin with the number "3", whereas those on the fourth floor begin with the number "4".

In addition to exhibitors housed in numbered booths, the National Bureau of Standards will have a display, but its location was not determined when the printed diagram was prepared.

	Booth No.
Allied Chemical & Dye Corp. (Barrett Divn.)	427-428
Aluminum Company of America	403-404-405
American Pipe & Construction Co.	415
American Smelting & Refining Corp. (Federated Metals Div.)	457
Ampco Metal Inc.	440
Apex Smelting Co.	444
Browne, Stewart R., Manufacturing Co.	439
Bureau of Standards	
Burgess-Parr Co.	438
Carey, Philip, Manufacturing Co.	424
Cathodic Protection Service	433
Cathodic Servicing Co.	308
Crose, M. J., Manufacturing Co.	448-449
Crutcher-Rolfs-Cummings	452
Dearborn Chemical Corp.	422-423
Dow Chemical Co.	418-419
Dow Chemical Co., (Saran Lined Pipe)	421
Duriron Co.	451
Ebasco Services, Inc.	456
Electric Railway Improvement Co.	432
Electro Rust-Proofing Corp.	303
Empire Steel Castings, Inc.	446
General Paint Corp., (Hill Hubbell & Co., Div.)	309
Grip Tite Oil Field Equipment Co.	453
Harco Corp.	443
Hills-McCanna Co.	447
International Nickel Co., Inc.	411-412
Johns Manville Sales Corp.	406-407
Koppers Co.	314-315
Lebanon Steel Foundry	408-409
Magnaflux Corp.	302
Midwestern Engine & Equipment Co.	312-313
Miller, M. C.	455
Minnesota Mining & Manufacturing Co.	417
Motorola, Inc.	437
Natasco Co.	310
National Carbon Co.	410
National Lead Co.	429-430
Nelson Electric Manufacturing Co.	420
Owens Corning Fiberglas Corp.	441-442
Perrault Bros., Inc.	301
Pipe Line Service Corp.	425-426
Pittsburgh Coke & Chemical Co.	435-436
Plastic Lining Corp.	402
Royston Laboratories, Inc.	445
Rust Oleum Corp.	307
Service Engineers, Inc.	434
Shell Oil Co.	311
Standard Pipeprotection, Inc.	401
Stearns, D. E.	413-414
Tapecoat Co.	431
Tretolite Co.	450
United Chromium, Inc.	454
U. S. Stoneware Co.	416
Westinghouse	304-305
Williamson, T. D., Inc.	306

Salt Water Corrosion Discussion Due

Special corrosion hazards and the measures that are taken to counteract them will be discussed during the Salt Water Corrosion Symposium at the NACE 1949 conference in Cincinnati, it was tentatively decided at a meeting of the NACE board in Cincinnati on January 13 and 14. This discussion is scheduled to follow the papers, "Corrosion of Steel Piling in Sea Water," by H. A. Humble of the Dow Chemical Company, Midland, Mich., and "The Deterioration of Steel Sheet Piling Groins at Palm Beach, Florida," by C. W. Ross of the Beach Erosion Board, U. S. Army Engineers. The data to be presented will be of immediate interest to the production departments of oil companies engaged in drilling from platforms in coastal waters.

Decision to arrange the program to include this discussion, conceded to be of major interest to those dealing with salt water corrosion problems, follows the policy of the Association to include insofar as practicable, material of timely value to those engaged in corrosion control measures. Considerable research in corrosion mitigation now is under way in all companies engaged in offshore drilling, and especially among those operating rigs on the edge of the continental shelf. So far no equivalent opportunity has been given those occupied with this problem to voice their problems and hear of remedial measures as will be provided by this discussion at the NACE conference.

Several members of the association have been engaged actively in both experimental and practical application of measures designed to mitigate the corrosive effects of a marine environment and it is believed that substantial benefit can be derived from the meeting of minds in which production personnel and the corrosion engineers working with them can air their problems, learn what remedial measures have been applied successfullly elsewhere under similar conditions and also the latest theoretical recommendations applicable to their problems.

While a good many of the corrosion problems faced by companies drilling in the coastal waters are parallel to those experienced by others in a marine environment, many especially difficult questions face oil companies operating rigs in relatively deep water. A case in point is the Humble Oil and Refining Company platform located off Grand Isle, 45 miles south of New Orleans, La. This operation comprises a two-decked platform 206 by 110 feet, surmounted by a rig the top of which is 255 feet in the air. The derrick floor is 60 feet above the water. Living quarters for 54 men are provided. The water is 50 feet deep beneath the platform.

This operation requires the delivery of every gallon of fresh water used from New Orleans, and storage of 15,000 feet of drill pipe, and storage of supplies for two weeks' operations in the even rough weather prevents supply ships from reaching the site.

The platform, built on 100 pilings, some designed to bear a 250,000-pound load, was constructed to withstand 120-mile winds and 35-foot waves.

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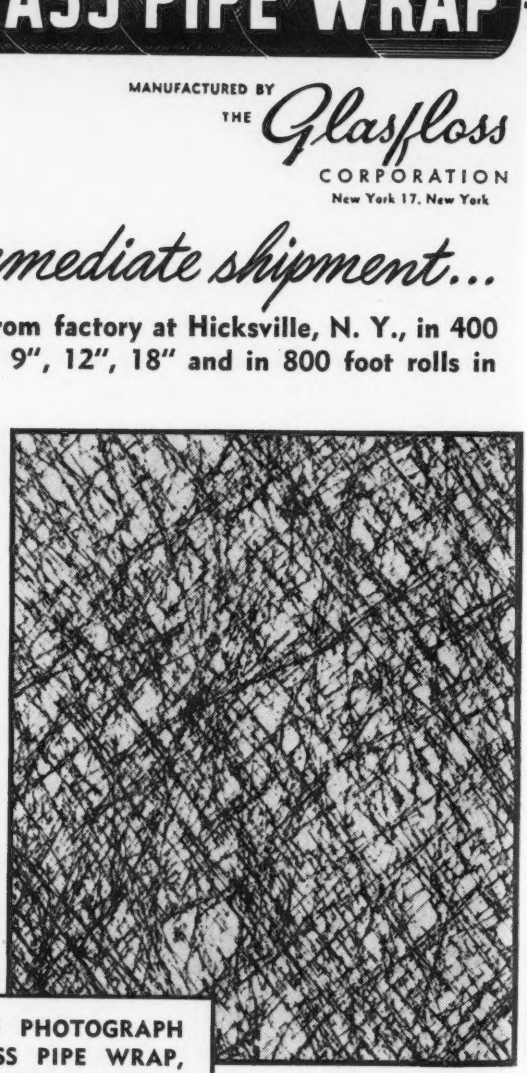

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Association Committees Will Meet

A tentative schedule of committee meetings to be held during the 1949 NACE conference at Cincinnati, Ohio, April 11-14 has been prepared by Maynard H. Jackson, chairman of the General Convention Committee. The list hereunder has been submitted to chairmen of committees for their comments and possible revision and may be altered substantially from its present form by the time the conference opens, it was pointed out by A. B. Campbell, executive secretary.

In addition to the meetings scheduled below plans are underway for an Inter-Society Corrosion Committee session. Time and place of the gathering, which is expected to include most of the affiliated societies' representatives, has not been determined yet.

The number in parentheses following the listing is a forecast of the number expected to attend each meeting. Where no number is found, no forecast has been made yet.

COMMITTEE MEETINGS NACE CONFERENCE

All meeting rooms are on the fourth floor of the Netherland Plaza Hotel. Committee members should consult the hotel's bulletin boards for confirmation of time and place.

SUNDAY, APRIL 10

10:00 a.m.—Executive Committee, F. L. LaQue, presiding (6).

1:30 p.m.—Board of Directors, First Meeting, F. L. LaQue, presiding (23).

MONDAY, APRIL 11

8:30 a.m.—Combined Meeting of Conference Committees, General Conference and Exhibition Committee, Maynard H. Jackson, chairman (49).

Technical Program Committee, Norton E. Berry, chairman.

Exhibits Committee, O. E. Murrey, chairman.

Local Arrangements Committee, V. V. Malcom, chairman.

9:00 a.m.—Publication Committee, Ivy M. Parker, chairman (8).

TP-4 Minimum Current Requirements for Cathodic Protection, A. V. Smith, chairman.

TUESDAY, APRIL 12

9:00 a.m.—Combination Meeting—Advertising Committee, Tom L. Holcombe, chairman, and Membership Control Committee, H. H. Anderson, chairman (20).

TP-3 Anodes for Impressed Currents, D. H. Bond, chairman (5).

DR. N. E. BERRY

Of Servel, Inc., Evansville, Ind., chairman of the Technical Program Committee for the 1949 Conference, has been in general charge of arranging for receipt and preliminary review of conference papers.

2:00 p.m.—Abstract Committee, Marquerite Bebbington, chairman (4).

3:00 p.m.—TP-5 Corrosion Problems in Processing and Handling Chemicals, M. G. Fontana, chairman (30).

TP-1 Corrosion of Oil and Gas Well Equipment, W. F. Rogers, chairman.

TP-2 Galvanic Anodes for Cathodic Protection, M. C. Miller, chairman.

4:30 p.m.—Officers and Symposia Chairmen, N. E. Berry, presiding (30).

WEDNESDAY, APRIL 13

9:00 a.m.—Policy and Planning Committee, H. M. Trueblood, chairman (8).

TP-6 Protective Coatings, G. W. Seargren, chairman (50).

TP-7 Materials for Use at High Temperatures, M. A. Scheil, chairman.

3:00 p.m.—TP-Corrosion by Waters, V. V. Kendall, chairman.

TP-9 Corrosion Inhibitors, A. Wachter, chairman.

Organic Coatings.

5:00 p.m.—Corrosion Correspondents.

TP-10 Corrosion Fatigue, V. V. Kendall, chairman.

O. E. MURREY

Of Midwestern Engine & Equipment Co., Tulsa, Oklahoma, chairman of the Exhibitors' Committee for the 1949 Conference, who has supervised arrangements for exhibits at the conference.

TP-11 Identification of Corrosion Products, C. M. Schwartz, chairman.

TP-12 Electrical Grounding Practices, H. L. Hamilton, chairman.

THURSDAY, APRIL 14

9:00 a.m—Exhibitors Meeting, L. A. Baldwin (50).

Regional Management Committee, F. J. McElhatton, chairman (8).

Annual Losses Due to Corrosion, K. G. Compton, chairman.

11:30 a.m.—Editorial Revue Committee, Paul Bachman, chairman (6).

3:00 p.m.—Technical Practice Committee, R. B. Mears, chairman (12).

FRIDAY, APRIL 15

9:30 a.m.—Board of Directors, President, presiding (23).

Inter-Society Corrosion Committee Heads Named

Balloting on nominations for officers of the Inter-Society Corrosion Committee has progressed sufficiently to establish that those nominated have been elected. The officers are:

Dr. H. H. Uhlig, Massachusetts Institute of Technology, Cambridge 39, Mass., chairman; Sam Tour, Sam Tour & Co., Inc., New York City, vice chairman; A. B. Campbell, NACE, Houston, Texas, secretary.

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Finest Conference Yet Is Predicted

By MAYNARD H. JACKSON
General Chairman
1949 Conference and Exhibition

As general chairman of the 1949 Conference and Exhibition it gives me pleasuse to advise it is going to be the finest yet from all viewpoints. When the excellence of past conferences and exhibitions is considered, this is making quite a statement. The splendid work of the committees has made the 1949 Conference possible. All have contributed time and effort unstintingly.

The technical program committee under Dr. N. E. Berry, chairman, has arranged eleven symposia covering many corrosion problems. The new symposium on "Corrosion Principles" should be very popular. Only two subjects, "Why Metals Corrode," by H. H. Uhlig, Massachusetts Institute of Technology, and "The High Temperature Corrosion of Metals," by Hugh J. McDonald, Loyola University, will be presented. Knowledge gained of fundamentals of corrosion should be of help to those who could use a little clearer understanding or a "refresher."

Soap Industry Problems

The chemical industry symposium includes papers on corrosion in the soap industry. The electrical and communications industries symposium has papers of interest to most members. Their story of corrosion mitigation has application to the installations of electrical apparatus in all industries. The cathodic protection symposium, a feature of interest to most members in the past, promises to be the same this year.

A "Pulp and Paper Industry Symposium" that covers a wide range of problems confronting that industry is expected to attract many.

The general industry symposium will have papers covering "Rust Preventives," "Erosion Corrosion of Metals and Alloys," "Potential Relationship between Zinc and Iron" and "Corrosion Characteristics of Titanium." The transportation industry symposium, a new feature this year, should attract considerable attendance from personnel of railroads, the automotive industry, airlines and aircraft manufacturers. Railroads have corrosion problems that cover those found in most other industries, encompassing underground pipe lines, communication and electrical systems, wharves and buildings.

The protective coatings symposium has papers covering the field from different viewpoints, from vitreous applications to chemical pretreatment. This symposium has been well attended for years by those desiring to keep abreast of latest methods and applications. The oil industry symposium always has had attendance of engineers from many oil companies because this industry was among the first to recognize the need of nationally spreading knowledge by the association. This year's program will satisfy their interest again.

Greatly increased interest in the subject of "Salt Water Corrosion" is expected.

Gas Engineers Coming

The gas industry symposium is popular for those interested in the solution of its problems. The usual large attendance is expected. The gas industry has contributed knowledge and research and recognizes the value of attending NACE meetings and probably will have even more engineers present this year than last.

The exhibition will comprise 75 booths displaying the products and services of 55 manufacturers. Booths will also be be occupied by the National Bureau of Standards and the National Association of Corrosion Engineers.

Social Events Planned

The local arrangements committee under V. V. Malcom, chairman, has handled the multitude of details required to make attendance a pleasure. Every effort is being made to make the conference something to remember. The "Friendship Hour" Monday evening will provide the means for all to get acquainted.

The ladies' activities have been carefully planned and, it is hoped, will be well attended. A ladies' headquarters room is available for meeting purposes as well as for getting information from the hostesses. The Cincinnati area has many points of interest and a sight-seeing trip is planned with stops at several fine places and luncheon.

The banquet Wednesday evening is the culmination of the year's activities. Introduction of new officers and many other features always are enjoyed by all. This is tied in with the business meeting Monday which also merits attendance. This marks six years of organizational progress. This is the opportunity for the membership to voice its wishes.

Arrangements committee personnel feel none can afford to stay away.

Because over 1000 attendance is expected, early reservations at hotels are urged.

Full Program for Ladies Is Promised

A program of luncheons, boasting pleasing menus, card parties, sight-seeing tours and shopping has been arranged for women guests by the local arrangements committee in Cincinnati for the 1949 conference to be held there April 11-14.

With the modernistic and luxurious Hotel Netherland Plaza as headquarters, all conference activities will take place in the midst of the Cincinnati retail district whose many attractive shops at that time will be filled with seasonal merchandise.

A sight-seeing tour including stops at the world-famous Rookwood Pottery, the Conservatory and beautiful Eden Park has been arranged. The Taft Museum also is included in the itinerary.

A detailed tentative program for the entertainment of women attending the conference with members or others interested has been released as follows:

Registration of women should be effected at the same time men are registered. Each man registering should remember to tell the person taking his registration the number of women accompanying his party.

Two buses, and a third if necessary, will leave the front entrance of the Netherland Plaza Hotel at 1:45 p.m. April 11. The itinerary includes half-hour stops at Rockwood Pottery and Eden Park Conservatory.

Ladies luncheon and cards will be held in Parlors A, B, C and D of the Netherland Plaza Tuesday, April 12 at 12:15 p.m. Maximum inclusive charge of the luncheon will be $3 each. Table prizes will be awarded. Favors will be given.

Ample space for incidental congregation will be available on the third floor foyer of the Netherland Plaza. Local committee members will be present to answer questions.

Titanium Corrosion Data to Be Given

What is believed will be the first authoritative presentation of data on the corrosion characteristics of titanium will be presented at the NACE 1949 conference in Cincinnati. The paper, by P. H. Permar of E. I. du Pont de Nemours & Co., Inc., Wilmington, Del., and G. E. Hutchinson, Remington Arms Co., Bridgeport, Conn., is entitled "Corrosion Characteristics of Titanium." Tentatively scheduled last of four papers in the General Industry Symposium, it is believed this paper will be of wide interest due to the growing research under way on the production of the metal.

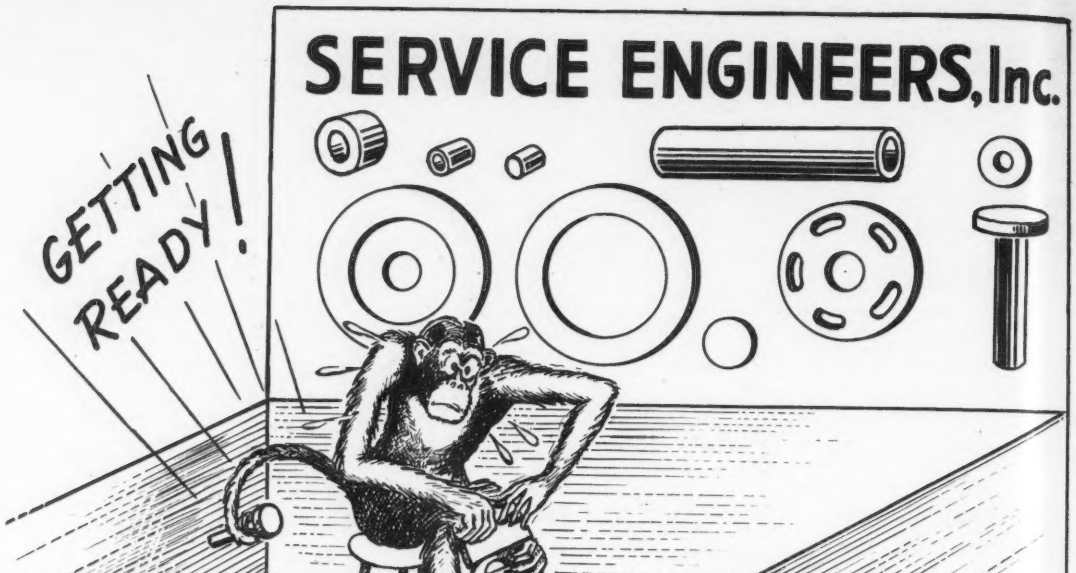
Although titanium has been known since about 1790, and has been widely used in compounds, pure metal has not been available in appreciable quantity. Vulnerability of the chromium supply of the United States, underlined by experiences during the war, and also of sources of tantalum and tungsten, alternate metals, caused intensification of investigations into sources and methods of production of titanium.

Until discovery of a new mine in eastern Quebec the world's largest known titanium mine was in New York state. The metal is considered the ninth most common in the earth's crust.

E. I. du Pont de Nemours recently has announced (Metals Review, November, 1948) it is prepared to furnish relatively large amounts of titanium sponge at $5 a pound. Kennecott Copper Corp. and the New Jersey Zinc Co. are reported ready to make a substantial investment in the newly discovered Quebec mine and Remington Arms Co. is now ready to furnish samples of unalloyed titanium in narrow sheets and small rods.

The Bureau of Mines has developed a workable process for production of ductile titanium made by magnesium reduction of the tetrachloride. It has a yield point of over 80,000 psi., double structural steel's strength, weighs 58 percent as much as steel, has a 3100° F. melting point but absorbs oxygen and nitrogen rapidly at temperatures above a red heat.

The iodide reduction process of reduction of the metal is being investigated at Batelle Memorial Institute.



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Technical Program Features Added

The following tentative technical program for the 1949 NACE conference in Cincinnati was released for March publication by Dr. N. E. Berry, chairman of the technical program committee. Numerous changes in titles, additions of authors, and in some cases changes of authors which have been made since the list was released for publication in February are included herein.

The schedule below includes titles of 43 papers and discussions in the Pulp and Paper Industry and Salt Water Symposia.

MONDAY, APRIL 11—SYMPOSIUM ON CORROSION PRINCIPLES.

2:00 p.m.—"Why Metals Corrode," by H. H. Uhlig, Massachusetts Institute of Technology, Cambridge, Mass.

3:00 p.m.—"The High Temperature Corrosion of Metals," by Hugh J. McDonald, Loyola University, Chicago, Ill., and Andrew Dravnieks, Illinois Institute of Technology, Chicago, Ill.

4:00 p.m.—General Business Session.

TUESDAY, APRIL 12—CHEMICAL INDUSTRY SYMPOSIUM.

9:00 a.m.—"The Pulse Polarizer in Corrosion Technology," by Hugh J. McDonald, Loyola University, Chicago, Ill., and Glenn A. Marsh, The Pure Oil Co., Northfield, Ill.

9:40 a.m.—"Physical and Corrosion Characteristics of Lead in the Chemical Industry," by Kempton H. Roll, Lead Industries Assn., New York.

10:20 a.m.—"Corrosion Tests in Processing of Soap and Fatty Acids," by W. Z. Friend and J. F. Mason, Jr., International Nickel Co., New York.

11:00 a.m.—"Plant Corrosion in the Fatty Acid Industry," by R. J. Paul, Emery Industries, Inc., Cincinnati, Ohio.

ELECTRICAL AND COMMUNICATIONS INDUSTRIES SYMPOSIUM.

9:00 a.m.—"Corrosion Protection of Power Transformers by Flow Coat Method," by Siebert L. Miller, Union Electric Co. of Missouri, St. Louis, Mo.

9:30 a.m.—"Alpeth—An Alternative to Lead Sheath in Telephone Cables," by Anthony Paone, American Telephone and Telegraph Co., New York.

10:10 a.m.—"Field Experience with Corrosion Protection of Galvanized Steel Substation Structures," by Siebert L. Miller, Union Electric Co. of Missouri, St. Louis, Mo.

10:40 a.m.—"The Use of Selenium Rectifiers as One-Way Valves in Electrolysis Drainage Wires," by W. D. Connon, Bell Telephone Co. of Pennsylvania, Philadelphia, Pa.

11:20 a.m.—"Corrosion Testing of Buried Cables," by T. J. Maitland, American Telephone and Telegraph Co., New York.

WEDNESDAY, APRIL 13—CATHODIC PROTECTION SYMPOSIUM.

9:00 a.m.—"Electrolysis Experiences on 115 KV. High Pressure, Oil Filled, Pipe Type Cable Installation in New Orleans," by S. E. Trouard, New Orleans Public Service, New Orleans, La.

9:40 a.m.—"Engineering Aspects of Cathodic Protection as Applied to Pipe Lines," by E. P. Doremus, G. L. Doremus and M. E. Parker, Cathodic Protection Service, Houston, Texas.

10:20 a.m.—"Cathodic Current Distribution in Some Zinc Steel Systems," by T. P. May, The International Nickel Co., New York, and George S. Gordon, Northwestern University, Evanston, Ill.

11:00 a.m.—"The Corrosion Products on Zinc Anodes Used Underground," by E. A. Anderson, The New Jersey Zinc Co., Palmerton, Pa.

WEDNESDAY, APRIL 13—PULP AND PAPER INDUSTRY SYMPOSIUM.

9:00 a.m.—"Major Corrosion Problems in the Pulp and Paper Industry," by Roy Whitney, Institute of Paper Chemistry, Appleton, Wis.

9:40 a.m.—"Panel Discussion of Corrosion Problems Occurring in the Pulp and Paper Industry," led by H. O. Teeple, The International Nickel Co., New York.

10:20 a.m.—"Cooperative Corrosion Testing in the Pulp and Paper Industry," by T. R. Gaulke, Research Metallurgist, and M. A. Scheil, Director of Metallurgical Research, A. O. Smith Co., Milwaukee, Wis.

11:00 a.m.—"Non-Metallic Lining Materials for Process Vessels in the Pulp and Paper Industry," by Beaumont Thomas, Chief Chemist, Stebbins Engineering and Manufacturing Co., Watertown, N. Y.

GENERAL INDUSTRY SYMPOSIUM

2:00 p.m.—"Field and Laboratory Evaluation of Petroleum-Base Rust-Preventives," by E. L. Walters and R. G. Larsen, Shell Development Co., Emeryville, Calif.

2:40 p.m.—"Erosion - Corrosion of Metals and Alloys," by M. G. Fontana, The Ohio State University, Columbus, Ohio, and W. A. Luce, the Duriron Co., Dayton, Ohio.

3:20 p.m.—"The Electrochemical Behavior of Zinc and Steel in Aqueous Media," by R. B. Hoxeng, Case Institute of Technology, Cleveland, Ohio, and C. F. Prutton, Carl F. Prutton and Associates, Inc., Cleveland, Ohio.

4:00 p.m.—"Corrosion Resistance of Commercially Pure Titanium," by P. H. Permar, du Pont de Nemours and Co., Inc., Wilmington, Del., and G. E. Hutchinson, Remington Arms Co., Bridgeport, Conn.

4:30 a.m.—"A Note on the Effect of Variations of the Exposed Area on the Solution Potential and Corrosion Rate of Low Carbon Steel," by J. M. Bialosky, Carnegie-Illinois Steel Corp., Pittsburgh, Pa.

TRANSPORTATION INDUSTRY SYMPOSIUM.

2:00 p.m.—"Corrosion Aspects of Fusion Welding Aircraft High Strength Aluminum Alloys," by L. W. Smith, Cornell Aeronautical Laboratory, Inc., Buffalo, N. Y.

2:40 p.m.—"Application of Corrosion Resisting Materials to Railway Electrical Construction," by H. F. Brown, New Haven Railroad, New Haven, Conn.

3:20 p.m.—"Electrolytic Corrosion of Steel in Concrete," by G. M. Magee, Association of American Railroads, Chicago, Ill.

4:00 p.m.—"Some Factors Influencing Corrosion in the Automobile Body," by W. R. Wiers, Fisher Body Division of General Motors Corp., Detroit, Mich.

THURSDAY, APRIL 14—PROTECTIVE COATINGS SYMPOSIUM.

9:00 a.m.—"Porcelain Enamel as a Corrosion Resistant Coating," by G. H. McIntyre, Ferro Enamel Corp., Cleveland, Ohio.

9:40 a.m.—"An Investigation of Shop Coat Structural Steel Primers," by S. C. Frye, Bethlehem Steel Co., Bethlehem, Pa.

10:20 a.m.—"Principles of Writing Specifications for Metal Protective Paints," by W. W. Cranmer, Industrial Testing Laboratory, Philadelphia Naval Shipyard, Philadelphia, Pa.

11:00 a.m.—"Cationic Chemical Pretreatment of Metallic Surfaces," by Wm. T. Deacon, Solvents and Plastics Co., St. Louis, Mo.

THURSDAY, APRIL 14—OIL INDUSTRY SYMPOSIUM.

9:00 a.m.—"Corrosion in Petroleum Processes Employing Aluminum Chloride," by R. S. Treseder, and A. Wachter, Shell Development Co., Emeryville, Calif.

9:40 a.m.—"Neutralization As a Means of Controlling Corrosion of Refinery Equipment," by E. Q. Camp and Cecil Phillips, Jr., Humble Oil and Refining Co., Baytown, Texas.

10:20 a.m.—Corrosion of Wet Steel by Hydrogen Sulfide-Air Mixtures," by D. C. Bond, Research & Development Laboratories, Winnetka, Ill.

11:00 a.m.—"Correlation Between Corrosion Survey Results and Actual Conditions," by I. B. Tietze, Phillips Petroleum Co., Bartlesville, Okla.

SALT WATER CORROSION SYMPOSIUM.

2:00 p.m.—"Corrosion of Steel Pipe by Chlorinated Sea Water at Various Velocities," by V. B. Volkening, The Dow Chemical Co., Freeport, Texas.

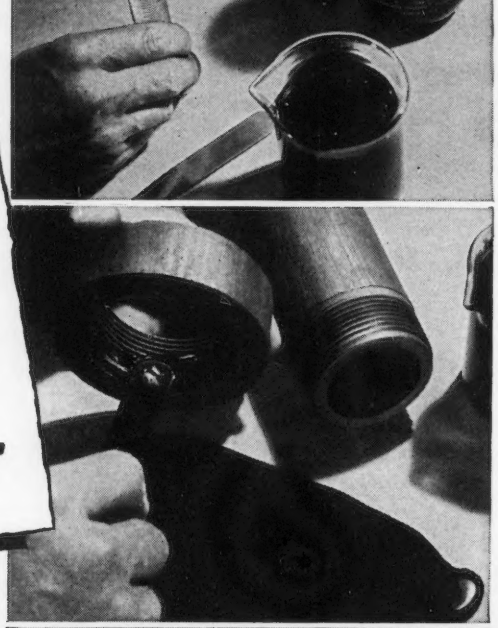
2:40 p.m.—"Some Experiments on the Resistance to Corrosion of Cast and Wrought Aluminum Alloys in Sea Water," by J. L. Basil and William C. Stewart, U. S. Naval Engineering Experiment Station, Annapolis, Md.

3:20 p.m.—"The Cathodic Protection of Steel Piling in Seawater," by H. A. Humble, The Dow Chemical Co., Midland, Mich.

(Continued on Page 21)

How to cement a "Karbate" threaded pipe joint

1. Thoroughly mix "National" cement with "National" accelerator in recommended proportions.



2. Pour part of the mixture onto a table and work it carefully into the threads of the collar...

3. Then work mixture into pipe threads...

4. Screw collar firmly in place and wipe off excess cement with acetone... the resulting joint is as strong and impervious as the pipe itself!

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TECHNICAL PROGRAM

(Continued From Page 19)

3:45 p.m.—"Deterioration of Steel Sheet Pile Groins at Palm Beach, Florida," by Culbertson W. Ross, Dept. of Army, Corps of Engineers, Beach Erosion Board, Washington, D. C.

4:10 p.m.—Discussion: Corrosion and Protection of Off-Shore Drilling Rigs.

GAS INDUSTRY SYMPOSIUM.

2:00 p.m.—"Cathodic Protection of Gas Distribution Systems," by C. L. Woody and A. W. Peabody, Ebasco Services Incorporated, New York.

2:40 p.m.—"Preparation of Pipe Surface During Reconditioning for Bitumen Coating," by O. C. Mudd, Shell Pipe Line Corp., Houston, Texas.

3:20 p.m.—"Technical Factors in Testing Pipe Line Coatings," by D. E. Stearns, M. W. Belson and Robert H. Lee, D. E. Stearns Co., Shreveport, La.

4:00 p.m.—"Field Tests of Sodium Chromates and Alkalies for Controlling Corrosion in Gas-Condensate Wells," by C. Kenneth Eilerts, R. V. Smith, F. G. Archer, L. M. Burman, Faye Greene and H. C. Hamontre, Bureau of Mines, Bartlesville, Okla.

Marine Biologist to Speak at Banquet

Scheduled featured speaker at the annual NACE banquet April 13 at the Netherland Plaza Hotel, Cincinnati, is Dr. William F. Clapp, a marine biologist of international reputation and recognized as one of the world's foremost authorities on the teredo. Dr. Clapp, 68, is credited with having "invented" the science of marine engineering, that branch of the art which consists primarily in designing and protecting installations in water.

He is a colorful and effective speaker, those who have heard him report, and it is believed his remarks will prove a highlight of the evening.

His career as a biologist began with the collection of snakes and insects prior to his entry into Harvard University in 1908. It was there, while assistant curator of mollusca that his interest in the teredo was awakened when samples of wood from San Francisco docks destroyed by borers were sent to the university. This led later to a decision to devote his time exclusively to the study of marine borers, a course which ultimately resulted in his becoming a widely-consulted engineer in this field.

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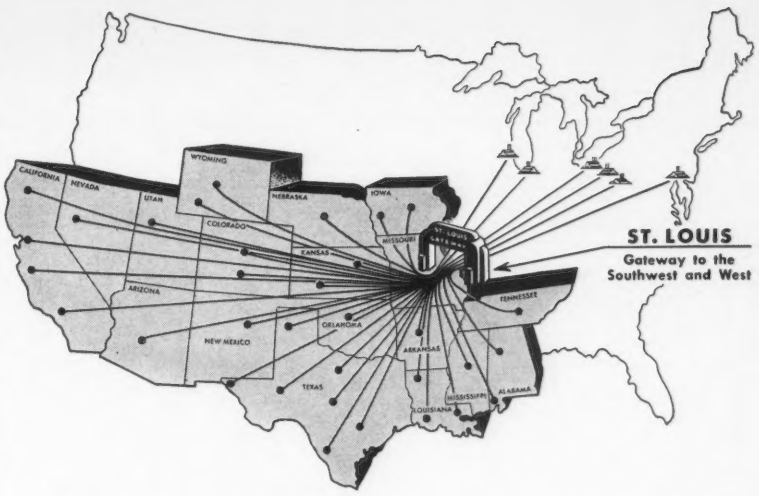

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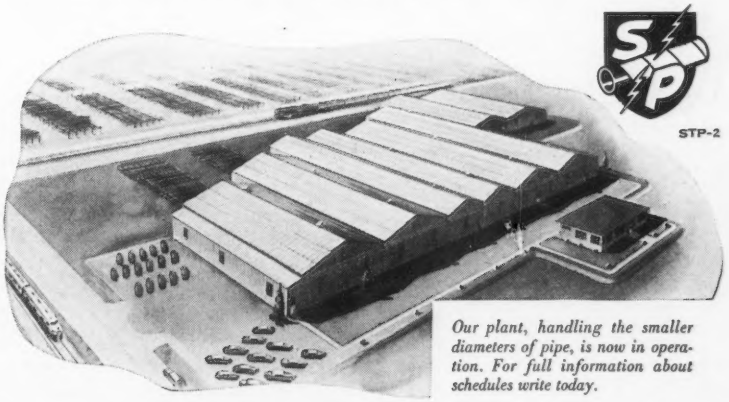

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Corrosion Abstracts

COATINGS

Selection of Protective Coatings for Metals. K. G. Compton, *Corrosion*, **4**, No. 3, 112-122 (1948) March.

Applications and properties of metallic and non-metallic coatings, and physical methods of testing coatings.—BNF.

Plastics for Corrosion Control. J. W. Shackleton, *Corrosion*, **4**, 172-178 (1948) Apr.

Discusses cellulosic plastics; polyvinyl alcohol; acrylic resins; vinylidene chloride; vinyl chloride resins; nylon, polythene and teflon; and their resistance to chemical attack.—BLR.

Rust Preventives. How They Work, What They Contain. H. Sellei, Nox-Rust Chem. Corp., *Chem. Ind.*, **62**, No. 1, 62-64 (1948) Jan.

The recent patent and periodical literature on rust preventives is reviewed on the basis of 42 references. The following topics are covered briefly: How corrosion occurs, main types of coatings, new specifications, improved products, chemical additives, petroleum vehicles, pigments and chromates, prospects. A table is included listing 12 temporary rust preventive coatings taken from government specifications. The information given includes the following: 1) object of protection, 2) specification, number and date of first issue, 3) designation of material, and 4) nature of material and coating.

Metallography of Hot-Dipped Galvanized Coatings. D. H. Rowland, *Amer. Soc. Metals Preprint No. 18*, 24 pp. (1947).

Article begins with a general discussion of hot dipping and points out that coatings produced by this process are essentially duplex in nature, consisting of a layer of the pure coating metal (or a solid solution) on top of an interfacial alloy which may itself be complex, being made up of layers of a number of different phases. In binary systems all the solid phases which appear in the constitutional diagram at the dipping temp. should be present in the coating in the order of their occurrence in the diagram. It has previously been difficult experimentally to demonstrate this owing to lack of a suitable etching reagent. The part played by diffusion in the growth of coatings is discussed. The Phase Rule shows that only single-phase diffusion layers can exist in binary systems; hence two-phase regions can only occur as interfaces between two single-phase layers. The results of the more reliable investigations of the iron-zinc diagram are summarized. Some experimental coatings were prepared by the immersion of 0.08%-carbon steel in a bath of Prime Western spelter at 450° C. for up to two hours. According to the iron-zinc diagram, these coatings should contain the following phases:

α, T. δ_1, ζ, $\zeta + \eta$, and η.

The existence of all these phases was confirmed metallographically with the aid of a new etchant containing 0.3 g. picric acid, 10 ml. ethyl alcohol, and 50 ml. water (the relative proportions of the three constituents are varied to suit different types of coating). Numerous photomicrographs from these specimens are reproduced. Curves are presented which show the rates of growth of the different phases. The different phases do not maintain their relative widths during growth; the Γ phase reaches max. thickness in one min.; the ζ phase grows rapidly at first but its rate of growth falls off, so that after 100 min. it is less than that of δ_1 phase. The results of Knoop hardness tests on the various phases are given. Some commercial coats also were examined. All the phases shown by the constitutional diagram were again shown to occur; the alloy layer consisted largely of ζ, except in the case of aluminum-bearing coats, when the predominant phase was $\zeta + \eta$. In galvanized coats, η was nearly absent, being replaced by ζ zinc-oxide. The presence of tin up to 1.0% does not affect the metallography. The author discusses the superior adherence of coatings on silicon-killed steel and suggests that this may be due to the thinness of the Γ layer in such coatings, and not to a mechanical locking effect as frequently supposed. The effect of aluminum in modifying the thickness of the coating is discussed, and an explanation is offered for the local flaking encountered with aluminum-bearing coats. The total thickness of aluminum-bearing coats may be revealed by etching first in dil. nitric acid (5 drops HNO_3/50 ml. water), drying, re-etching in ferricyanide reagent (0.5 g. $K_4Fe(CN)_6$, 50 ml. water, 50 ml. alcohol, 2 ml. NH_4OH), and finally brushing with amyl alcohol.—MA.

Classification and Uses of Plastic Coatings. L. J. Robertson, *Oil and Gas J.*, **47**, 72+ (1948) May 6.

Treated from point of view of protection of oil-well, pipeline, and refinery equipment.—BLR.

Profits in Metallizing by Industrial Plants and Shops. W. C. Reed, *Sou. Mach. & Metals*, **3**, 10-13+ (1947) Feb. 10. *Corr. & Mat. Prot.*, **4**, No. 5, 20 (1947) Sept.-Oct.

Includes consideration of corrosion-resistant coatings for atmospheric exposure and immersion in cold fresh water.—INCO.

Abstract Section Style Outlined

For ease in locating reference data, CORROSION uses a uniform style in its Abstract Section.

The abstracts first are broken down into major classifications of the more common types of corrosion literature. In each review the title of the article is presented in bold face type, followed by the author's name. The publication from which the article was abstracted is printed in italics and is abbreviated in most instances. Following this, in sequence, are the volume (bold face), number in the volume, pages, year and month of publication. In some instances a second reference will be listed in the same manner. This indicates that the article also was published or abstracted in another publication. A brief summary of the article follows the above information and it is concluded with an abbreviation indicating the source of the abstract and contributor. The meanings of these abbreviations usually are listed on the first page of the Abstract Section.

When seeking more detailed data about an abstract, best source of information is the publication in which the article appeared originally. (Listed in italics in the heading.) The contributor of the abstract also may be able to supply additional information. Addresses of most of these publications may be found in the reference section of most public libraries.

Abbreviations at the end of abstracts indicate source of abstract and contributor; and are as follows:

AER	*Aeronautical Review*, Institute of Aeronautical Sciences, Inc.
ALL	*The Abstract Bulletin*, Aluminum Laboratories, Ltd.
AWWA	*Journal*, American Water Works Association
BLR	*Battelle Library Review*, Battelle Memorial Institute Library
BNF	*Bulletin;* British Non-Ferrous Research Association
CALCO	Calco Chemical Division, American Cyanamid Corp.
CE	*Chemical Engineering*, McGraw Hill Publishing Co.
CEC	Consolidated Edison Co. of New York, Inc.
EW	*Electrical World*, McGraw Hill Publishing Co.
GPC	General Petroleum Corp. of California
INCO	The International Nickel Co., Inc.
IP	Institute of Petroleum
MA	*Metallurgical Abstracts*, Institute of Metals, London, Eng.
MR	*Metals Review*, American Society of Metals
NBS	National Bureau of Standards
RA	*Refrigeration Abstracts*, American Society of Refrigeration Engineers
RM	*Revue de Matallurgie*, Paris, France
RPI	*Review of Current Literature Relating to the Paint, Colour, Varnish & Allied Industries*, Research Association of British Paint, Colour & Varnish Manufacturers, London.
TDD	*Technical Data Digest*, Air Materiel Command—Technical Service Section
UOP	Universal Oil Products
No Code	*Current Technical Literature*, Bell Telephone Laboratories

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Experiments on the Production of Protective Coatings on a Zinc-Aluminum-Copper Alloy by Anodic Oxidation. O. Kubaschewski, H. Ebert and H. Schmid, Min. of Supply, RTP/TIB Translation No. GDC 205T, 4 pp. from *Kaiser Wilhelm Inst. Metallforschung Report.*

Experiments were carried out on a heterogeneous zinc-base alloy with 32% aluminum, 2.8% copper, 0.05% magnesium. A considerable range of electrolytes was used for the anodic oxidation, but the treated specimens showed lower resistance to sea water than the untreated, even if the film was impregnated (e.g. with wax).—BNF.

Protective Coatings for Standpipes. Alfred F. Howard, *J. Maine Water Works Util. Assoc.*, **23,** 51 (1947) May; *J. Amer. Water Works Assoc.* (Abs.), **40,** 366 (1948).

States the corrosion problem in tanks could probably be eliminated by the use of nickel-clad or stainless-steel-clad, but the costs of these materials are at present prohibitive. Electrical rust-proofing by the cathodic method has been used in many places, but ice formation is a factor against its use in Maine. Author's company has had bad experience with emulsified asphalt as a coating. For good results, preparation of the surface is of chief importance. Deep tubercules must be sand-blasted or flame-treated. Paint must be brushed on a dry surface. Lead is used in the prime coats only in drinking-water tanks and is covered with two aluminum paint coats. This is satisfactory when the water has a pH of 6.4.—MA.

Obtaining a Homogeneous Film on Aluminum and Its Alloys by Anodic Oxidation. J. Hérenguel and R. Segond, *Rev. Met.*, **42,** No. 8, 258-265 (1945); and *Bull. Soc. Franc. Met.*, No. 1, 44-51; Discussion, 52 (1945); also abridged translation, *Metal Ind.*, **70,** No. 1, 3-5 (1947).

Under certain conditions, anodic oxidation produces a film consisting of two layers, the outer one soft and the inner hard. On Duralumin, such heterogeneity appears with high c.d., there is a clear demarcation, and the outer layer is easily detached; with aluminum and aluminum-magnesium alloys, the transformation from one layer to the other is progressive, and the inner one is fibrous in character. The controlling factors are: c.d., temp. and concentration. All experiments were made with a 10% sulphuric acid bath. With aluminum, the film becomes discontinuous above a limiting c.d., and beyond a further limit the film is heterogeneous; in each case there is a linear relationship between the c.d. and the temp., the limits for homogeneity being 1 and 3 amp./dm.^{2} at 30° and 25° C., respectively. For aluminum-magnesium alloys, the temp. must be 20° C. at 2.5 amp./cm.^{2} With Duralumin, the working limits are further reduced; a temp. of 14° C. is required at 1 amp./dm.^{2} In this case a thinner film is obtained and with greater difficulty. In all three cases, the limiting c.d. is reduced by raising the acidity of the bath. Values for the thickness of the film formed with a const. treatment time of 45 min. have been determined. Heterogeneous films are less durable, take dyes irregularly; and give bad adhesion of paint or other coatings.—MA.

Protective Coverings for Marine Applications. Rolt Hammond, *Paint Manufacture*, **18,** 79-83 (1948) March.

Reviews effects of marine fouling; fouling characteristics of ports; plant fouling; anti-fouling studies; effect of toxins; recent research results; uses of asphalt; bituminous paints; protection of internal surfaces; Admiralty Corrosion Committee tests; use of plastics; and flame-spraying applications. Twelve refs. —BLR.

Effect of Driers on the Chemical and Water Resistance of Aged Varnish Films. G. W. Gregg and Another, *Off. Digest Feder. Paint & Varnish Prod. Clubs*, No. 270, 421-429 (1947); *Chem. Abst.*, **41,** 6735 (1947) Oct. 20.

Six drier compositions were incorporated in three commonly used types of varnish, and films from these compositions were tested for resistance to hot and cold water, 3% alkaline solutions and soap solution after ageing for 3, 14, 30, 60 and 90 days. Driers used.—INCO.

Factor in the Selection of Protective Coatings. Allen G. Gray, *Prod. Finishing*, **12,** No. 1, 70, 72+ (1947).

A review of a paper presented by K. G. Compton to the Protective Coatings Division, Spring Regional Conference of the Chemical Institute of Canada. The fundamental mechanism of corrosion briefly is surveyed and the basic properties of various types of protective coating considered.—MA.

Recent Developments in the Use of Conversion Coatings on Zinc-Plated Steel. Allen G. Gray, *Prod. Finishing*, **12,** No. 2, 50, 52+ (1947).

A detailed review of a paper presented by J. E. Stareck and W. S. Cibulskis to the 34th Annual Convention of the American Electroplaters' Society.—MA.

Metal Coatings by High-Vacuum Evaporation. P. Godley, *Iron Age*, **161,** No. 14, 90-94 (1948). Apr. 1.

Describes further industrial development of this method of coating. A very large variety of applications are quoted. —BNF.

Metal Surface Protection by Tin Diffusion. *Engineers' Digest* (American Edition), **5,** 155-156 (1948) Mar.-Apr. Translated and abstracted from *Metalloberflache*, **1,** 185-187 (1947) Aug.

Outlines procedures developed for above and results obtained. It can be applied to copper, copper alloys, and steel. Investigations in German shipyards have proved the good corrosion resistance of the protective layer and its applicability to high-pressure work.—BLR.

Electrostatic Methods (of Protection of Die-Castings). *Die Castings*, **5,** No. 11, 57 (1947).

Electrostatic spraying and electrostatic detearing are discussed.—MA.

Electroless Plating (of Nickel and Cobalt) on Metals by Chemical Reduction. *Chem. Eng. News*, **25,** No. 31, 2222 (1947).

A note on the deposition of nickel and cobalt on metallic surfaces by the reduction of nickel or cobalt salts with hypophosphite in hot solutions (90° C.). Cobalt and cobalt-nickel alloys are obtained from ammoniacal solutions; nickel from either acid or alkaline solutions. The reaction is catalytic and is only initiated by the introduction of iron or steel, nickel, gold, cobalt, palladium or aluminum into the solution.—MA.

Detel—Anti-Corrosive Coatings. *British Chem. Digest*, **2,** No. 2, 64-65 (1947) Nov.

A new chlorinated rubber, registered as Detel, is announced for corrosion-resisting coatings by Detel Prods., Ltd. A second type of coat, called Detel Metal Undercoat (D.M.U.), contains over 90 percent zinc, and can be painted on with a brush or sprayed on. These coatings have been used successfully for protecting iron and steel work on piers, shelters and coastal installations, chemical, fertilizer, gas, dye and oil plants, electro-deposition baths, ships, harbor and dock installations, breweries and food process equipment. Introduction says 30,000,000 lbs. worth of steel and iron piping is wasted each year through corrosion, and 30,000,000 tons of ferrous materials are lost annually this way. (See *Brit. Chem. Digest*, March, 1947, p. 232.)—INCO.

Stainless Steel Paint Offers Corrosion Resistance, Hardness and Attractive Surface. G. Black, International Nickel Co., *Mat. and Meth.* **27,** No. 4 86-7 (1948) Apr.

18-8 Stainless steel flake made into a paste with 14 percent Varsol as a solvent and 1 percent stearic acid to facilitate leafing is recommended for coating paper, paper products, wire, metal frames. For maximum corrosion resistance, a vehicle containing chlorinated rubber and vinyl resins is used.—INCO.

Analysis of Heat Resistant Paints. G. Black, International Nickel Co., & H. Sanders, *Prod. Eng.*, **18,** No. 12, 85-87 (1947) Dec.

Review of heat-resisting paints, giving ideal requirements and need for specification standards. Two Diesel engine mufflers were exposed to a temperature of 510° F. and weathering in a corrosive atmosphere.—INCO.

Plating Zinc on Magnesium. *American Metal Market (U.S.A.)* **55,** No. 75, 1, 5 (1948) April 20.

Dow Chemical Company recently has developed a new method for electroplating zinc on magnesium. First step in this process is to remove all contamination and provide the correct reactive surface to promote good adhesion and a continuous deposit. This is followed by a bath treatment which deposits an extremely thin zinc film on the surface of the magnesium. After this, all plating is done in commercially used baths and is typical of plating any metal. Electrodeposits of any of the commercially plated metals, such as chromium, silver, gold, copper, brass, cadmium or zinc may be applied to any commercial magnesium alloy. The zinc coating has shown excellent adhesion, wear and resistance to accelerated corrosion. Parts have been hammered and severely rubbed without disturbing the deposit, and the finish has withstood heat, humidity and salt spray tests satisfactorily. The new finish may be used on automotive and building hardware, optical equipment, and sporting goods, etc. Experiments on magnesium engraving plates which have been chrome plated show outstanding results in wear resistance. A wide variety of uses of plated magnesium to provide both increased wear resistance and decorativeness, is expected for the future.—ALL.

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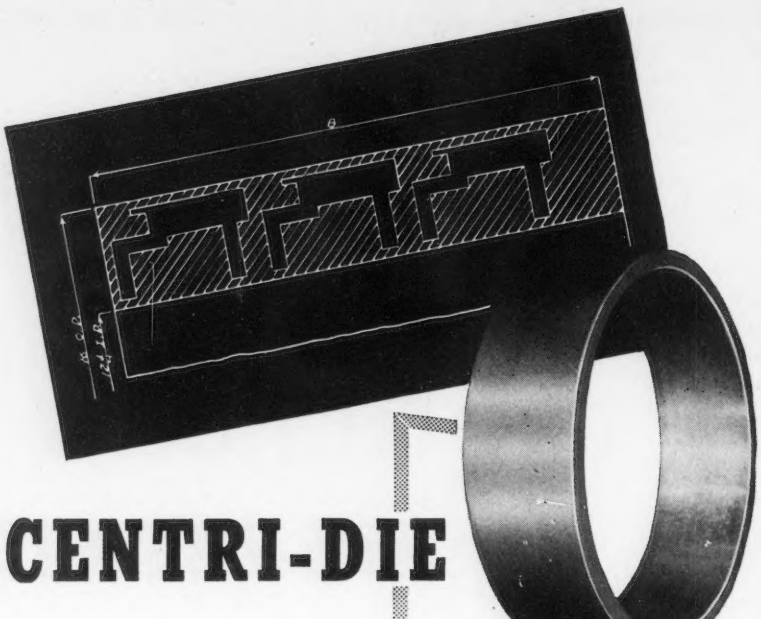

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Electroless Plating (of Nickel and Cobalt) on Metals by Chemical Reduction. *Prod. Finishing,* **11,** No. 12, 54-58 (1947).

A review of recent work done by the U. S. National Bureau of Standards on immersion deposits of nickel, cobalt, and nickel-cobalt. An adherent coating is formed which is of good quality and generally bright, though brittle. The coating can be made hard and a suggested use is in applications where wear resistance is important. The solutions used are fairly complex and all contain a hypophosphite, which, with the catalytic initiation of the metal to be plated, reduces the nickel or cobalt salt to the metallic state. No reduction takes place except in the presence of iron or steel, nickel, gold, cobalt, palladium, or aluminum. The rate of deposition is 0.0002-0.0008 in./hr. Solutions are used hot, and pH needs fairly close control, but composition is not critical. Full details are given of two nickel baths, one cobalt bath, and one nickel-cobalt bath. The ductility of the deposits is improved by heating. The protective effect of the nickel coatings is about the same as for electrodeposited ones, but the cobalt coatings are inferior to electrodeposited cobalt.—MA.

Rust Preventive Compounds. H. B. Carpenter, Standard Oil Co. of N. J., Paper before AISE Ann. Conv. Cleveland, Oct. 3, 1946, *Iron & Steel Eng.,* **24,** No. 9, 73-78 (1947) Sept.

Use of rust preventive compounds to eliminate corrosion is more economical than later removal of the rust. Principal function of rust preventive compounds is to act as a moisture barrier. They are not rust removers, and are effective only when applied to surfaces which are thoroughly clean and dry. The non-hard-drying compounds have a petroleum base and are characterized by their ease of removal with petroleum solvents without adverse effect on the metal surface to which they have been applied. The hard-drying group are of the so-called lacquer type and provide a film which is hard enough to resist the abrasion encountered in shipping, and yet sufficiently flexible to withstand the tendency of the expansion and contraction of the metal to cause cracking. Laboratory methods for the evaluation of performance include humidity cabinet, salt spray and water spray tests. Methods of application are discussed. Compounds can be considered for machinery or equipment kept in stand-by storage without disassembly, tools and spare parts in storage, and finished products.—INCO.

Protective Coverings for Marine Applications (2), (Concluded.) *Paint Mfr.,* **18,** 129-131 (1948) Apr.

Covers wire-process spraying; zinc-spraying results; protection of propellers; other metal spraying applications; and scope of metal spraying in marine protection.—BLR.

Organic Coatings for Metals. E. E. McSweeney, *Plating,* **35,** 340-343 (1948) Apr.

Deals primarily with the composition in relation to performance. Discusses the various factors which should be considered in selecting a coating for a specific application, including the cost item; wherein cost per finished article is said to be more important that cost per gallon.—BLR.

CHEMICAL

Some Developments in Corrosion-Resistant Material for Chemical Plant. N. P. Inglis, Paper, Soc. Chem. Ind. Glasgow Sect. (1948) Mar 5; abstr. *Chem. & Ind.* No. 13, 202-203 (1948) Mar. 27.

In a discussion of corrosion-resistant metal alloys, it is pointed out that fabrication operations may affect the properties of the metal, e.g. "weld-decay" is caused by 18/8 chrome-nickel steel by the precipitation of chromium carbide from the solid solution structure at welding temperatures. The addition of titanium to the steel, fixing the carbon as titanium carbide, results in satisfactory resistance to the "weld-decay," although the modified steel is slightly less corrsion-resistant. Since the resistance of this steel is due to passivity rather than to inherent nobility, it should be used only under conditions which favor the formation and self-healing of protective oxide film. The effect of adding molybdenum to steels is discussed. The fabrication properties of the 25-30% chromium steels and the 25/30 chrome-nickel steels are mentioned. The use of metals other than steels for chemical plant construction is discussed briefly.

Resistant Lining for Alum Boiling Tanks. Edward S. Hopkins, *Chem. Eng.*, **55,** 102-105 (1948) Mar.

Failure of lead linings in alum-boiling tanks led to development of a thermoplastic, non-porous, flexible membrane bonded directly to the steel tank wall and faced with acidproof brick which promises to last twice as long and to have a cost per ton of alum produced of less than one-fourth of lead lining.—BLR.

The Cracking Corrosion of Steels in Nitrates. E. Herzog, Paper before Journees Metallurgiques d'Automne (Fall Metallurg. Conf.) sponsored by Soc. Francaise de Metallurgie and Comm. Tech. des Etats de Surface, Paris, Oct. 6-10, 1947 (Abst. in French).

Additions of 1-4% chromium, 1-2% aluminum and 1-5.6% nickel retard the intercrystalline corrosion of aluminum-killed mild steel to a certain extent.—INCO.

Experiments on the Corrosion of Porous Bronze Compacts Produced by Powder Metallurgy. M. M. Hallett, *J. Soc. Chem. Ind.*, 67, No. 2, 57-61 (1948) Feb.

Tests on behavior of porous bronze compacts towards a range of acids, alkalis and salts under aerated and in some cases under stagnant conditions, in comparison with the behavior of a solid bronze under the same conditions. Both the compact (Porosint) and the solid (cast) bronze contained 11.4% tin.—BNF.

The Mechanism of Protective Action of Alloying Elements in the Sulphide Corrosion of Iron. P. V. Geld and O. A. Essin, *Brit. Chem. Digest,* **2,** 225-227 (1948) Apr. Translated and condensed from *J. of Applied Chemistry (USSR),* **19,** No. 9 (1946).

Discusses diffusion coefficients on basis of protective action of alloying elements, alloying elements with a similar affinity for sulfur as for iron, and alloying elements with higher affinity for sulfur than for iron.—BLR.

Some Case Histories of Corrosion Problems in Chemical Process Equipment (Nickel Alloys). W. Z. Friend and F. L. LaQue, *Petroleum Eng.*, **18,** No. 10, 212-220 (1947).

Seven cases involving unexpected corrosion are discussed. These mostly refer to nickel alloys. It is stressed that failure to recognize the presence of, or to anticipate the effects of, certain factors often lead to unexpected corrosion. Among the factors examined are: the importance of aeration or lack of it; temp. of the solution of metal; velocity; presence of minor, but highly corrosive, constituents; presence of constituents that destroy the protective film; absence of constituents expected to inhibit corrosion; unfortunate combinations of metals with unfavorable area ratios that lead to galvanic corrosion; concentration cells responsible for localized corrosion, and improper heat-treatment of the metal. —MA.

Development and Use of a 600-Ampere Fluorine Cell. R. D. Fowler, W. B. Burford, H. C. Anderson, J. M. Hamilton, Jr., and C. E. Weber, *Ind. Eng. Chem.*, **39,** 266-271 (1947); Brit. Abs. *BI,* 255 (1947) Sept.

Design and operation of a cell working at 250-360°, utilizing KHF_2 as the electrolyte, is described. The body of the cell and the diaphragm are constructed of Monel. With the exception of the copper anode bar, corrosion of the cell is slight. Polarization depends on the quality of the carbon of the anodes and becomes worse as the anodes age.—INCO.

Microbiological Problems in the Manufacture of Sugar from Beet. I.—Corrosion in the Diffusion Battery and in the Recirculation System. L. A. Allen, F. Wormwell, T. J. Nurse and Others, *J. Soc. Chem. Ind.*, **67,** No. 2, 70-77 (1948) Feb.

Corrosion by hot extraction liquor was shown to be due to acid produced by aerobic thermophilic bacteria; some amelioration of the trouble was obtained by heavy chlorination.—BNF.

CONSTRUCTION MATERIAL

Investigation of Corrosion of Cast Iron Molds by Aluminum and Nonferrous Alloys Containing Silicon. ("Alpas" and Liquid High-Silicon Alloys.) (In French.) Paul Bastien and Suzanne Daaschner, *Fonderie,* 962-964; Discussion, 964-965 (1947), Dec.

Ordinary gray cast iron proved most satisfactory with respect to corrosion caused by liquid aluminum. In the case of "Alpex" or high-silicon alloys in the liquid state, the best results were obtained with malleable cast-iron molds.—BLR.

Reynolds to Show Aluminum at Petroleum Exposition. *American Metal Market (U.S.A.)* **55,** No. 85, 3 (1948) May 4.

The Reynolds Metals Co. mobile unit will display aluminum piping at the International Petroleum Exposition, Tulsa, Okla. Among the new uses to be shown will be welded pipe line fittings, special couplings, samples of coated pipe for underground use, threaded pipe for shothole casings and other special items. The display coach is a regular 48-passenger Twin-Coach bus remodeled to display Reynolds aluminum products. The coach interior is finished in aluminum with green aluminum wall tile and aluminum venetian blinds. It carries a series of panels showing the complete story of aluminum from the raw ore to the finished product.—ALL.

Aluminum Used in Combating Tank Corrosion. Gordon W. Alexander. *Petro. Refiner,* **26,** No. 12, 99 (1947).

A brief note on the use of aluminum for storage-tank roofs in the petroleum industry in order to combat corrosion by hydrogen sulphide and free sulphur. The tanks in question were run-down tanks for the gasoline cut from the thermal cracking unit. Steel roofs suffered serious corrosion in this application. Four-inch steel channel sections were used as rafters, but placed on the top side of the aluminum sheet. The roof sheets were fabricated in 90° segments and then fitted to the tank. Aluminum rivets were used, and lead was employed as a gasket material to make the joints vapor-tight. —MA.

Condenser Tube. *Chem. & Eng. News,* **26,** No. 12, 891 (1948) March 22.

A copper-nickel condenser tube for installations where severe operating conditions obtains is of 88.5% copper-10% nickel-1.5% iron. It is recommended particularly for marine and utility installations encountering high velocities, high temperatures, brackish or salt water and bad pollution. Announced by Revere Copper & Brass, Inc.—INCO.

Sodium Chloride vs. Construction Materials—I, II, III, IV. Corrosion Forum, *Chem. Eng.*, **54,** No. 10, 211-212+ (1947) Oct.; No. 11, 217-218, 220 (1947) Nov.; No. 12, 225-226+ (1947) Dec.; **55,** No. 1, 223-224, 226 (1948) Jan.

Manufacturers' symposium with articles as follows:

Part I. Chemical Porcelain, by J. S. Chowning (Lapp Insulator Co., Inc.) Iron & Steel, by A. W. Spitz (Am. Cyanamid Co.). Silicones, by J. A. McHard (Dow Corning Corp.). Worthite, by W. E. Pratt (Worthington Pump & Machinery Corp.).

Part II. Carbon Graphite, by L. C. Werking (National Carbon Co.). High-Silicon Irons, by W. A. Luce (Duriron).

Part III. Nickel, Nickel Alloys, by W. Z. Friend (Inco). Lead, by H. M. Church, Jr. (Lead. Inds. Assoc.). Precious Metals, by E. F. Rosenblatt (Baker & Co.). Protective Coatings (Anon.). Rubber Lining, by O. S. True (U. S. Rubber). Tantalum, by L. R. Scribner (Fansteel Metallurgical Corp.).

Part IV. Aluminum, by J. P. Balash (Alcoa). Chemical Stoneware, by F. E. Herstein (Gen. Ceramics & Steatite Corp.). Durimit & Chlorimet, by W. A. Luce (Duriron). Hastelloy, C. G. Chisholm (Haynes Stellite). Haveg, by E. P. Mampe (Haveg Corp.). Stainless Steel, by G. L. Snair, Jr. (Allegheny Ludlum Steel Corp.)—INCO.

GENERAL

Corrosion Engineer Evolves as New Specialist, *Chem. and Eng. News,* **26,** No. 16, 1145 (1948) Apr. 19.

Speaking before the annual conference of the National Association of Corrosion Engineers in St. Louis, April 5-8, Mr. K. Tator accounts for the rapid growth

of the National Association of Corrosion Engineers by the fact that corrosion plays such an important part in the maintenance and cost of any equipment. He pointed out that the annual cost of corrosion and the concomitant remedial measures in the chemical industry is often 100 percent of the original plant cost. The use of the electron microscope in studying the nature of protective or non-protective corrosion films on metals and alloys was discussed by E. A. Gulbransen, Westinghouse Electric Corporation. The complexity of oxides and differences in oxides in thick and thin films were two of the complicating factors mentioned. An important advantage cited was the fact that the outside few layers of atoms are studied for a case of a perfectly flat surface; if the material forms a surface with smaller crystallites of the order of a few hundred to a thousand Angstroms in size projecting into the beam, all of the material formed in the reaction will be penetrated. J. W. Ryznar and J. Green of the National Aluminate Corp. described a test for screening possible corrosion inhibitors and their evaluation. The test involved the rotation of a solid steel specimen, 0.25 in. in diameter, at constant speed for 24 hours in the test water, with visible evaluation of the results.—ALL.

Metallurgical Methods for Combating Corrosion and Abrasion in the Petroleum Industry. B. B. Morton *J. Inst. Petr.* **34,** 1-68 (1948) Jan.

The action of corrosion and also of abrasion within the petroleum industry results in the wasting away of important material and the early retirement or destruction of equipment that is unprotected. The object of this paper is to review steps that have been taken within the petroleum industry of the United States to counteract such destruction and especially to outline recent metallurgical developments within the industry. 18 references.—GPC.

Present Tendencies in Research on Corrosion. (In French.) Paul Lacombe, *Metaux & Corrosion,* **22,** 181-184 (1947) Nov.-Dec.

A general summary of new methods for protection against corrosion and for corrosion testing described at International Conference on Corrosion, Paris, Oct. 6-10, 1947.—BLR.

The Corrosion Handbook H. H. Uhlig (Editor), Book, 1948, 1188 pp. John Wiley & Sons, New York (Chapman & Hall, Ltd. London). $12 (to members of the Electrochemical Society, $8).

This is a co-operative effort, sponsored by the Electrochemical Society. Over 100 authors have contributed, and there are sections on corrosion theory; corrosion in liquid media, the atmosphere and gases (many metals and alloys considered separately); special aspects of corrosion; materials resistant to high temperature; materials resistant to chemicals; protection; corrosion testing. Some attention is given to non-metallic materials. (This book is at present available in the original American edition. The British edition is in preparation.)—BNF.

Dezincification and Erosion-Corrosion. *Mars G. Fontana, Metal Prog.,* **53,** 686-689 (1948) May.

Third part of a 4-installment article on "The Eight Forms of Corrosion."—BLR.

Steam Turbine Lubrication Problems and Their Solutions. 5. "Secondary" or "Acid Condensate Corrosion" Rusting (1). *Petroleum,* **11,** 86-87 (1948) Apr.

Reviews previous articles of series. Discusses mechanism of "secondary" rusting and its prevention; and the oxidation of solvent-refined and "conventionally" refined turbine oils. (To be continued.)—BLR.

Some Recent Investigations on Corrosion and Metallurgy. N. T. Belaiew, *Sheet Metal Ind.,* **24,** No. 248, 2469-2470 (1947).

A brief review of a conference held under the joint auspices of the Societe Francaise de Metallurgie and the Commission Technique des Etats de Surface.—MA.

Corrosion Prevention Begins with Construction. W. E. Huddleston, *Petro. Eng.,* **19,** No. 6, 154 (1948) Mar.

The complete insulation of pipe lines during construction affords the following advantages: 1) a substantial amount of corrosion that would otherwise occur along the pipe line due to galvanic action will be eliminated; 2) the inception of stray currents will be opposed, which will further reduce the corrosion tendency; 3) after having eliminated the above described sources of trouble, the pipe line may be maintained entirely free from external corrosion at very low cost, using a moderate amount of cathodic protection. The plans for insulating, the avoidance of interference, insulating by coating castings, insulating castings with special insulators and insulating of wells are discussed.

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METAL FAILURE

Erosion in Vent Plugs—The Effect of Vent Diameter—I and II. J. H. Wiegand, Aberdeen Proving Ground, *J. Franklin Inst.*, **244,** No. 4, 291-308 (1947) Oct.; No. 5, 363-384 (1947) Nov.

Previous work on gun erosion is reviewed. Erosion in a vent first was shown to be a function of flame temperature of powder gases. Then the relative erodibility of metals was established and the melting point of metals found to be important. Most comprehensive work was by Greaves, Abram and Rees (1929) who studied all previous work and concluded erosion was due to melting of vent surface which starts at a definite pressure. Their experiments covered plain carbon steel, low nickel-chromium and nickel-chromium-molybdenum steels, high-chromium and nickel-chromium stainless steels, nickel-copper alloy and pure nickel. Data are tabulated and pertinent graphs included, covering effect of flame temperature of powder on min. charge to produce melting of low alloy nickel chromium and nickel-chromium-molybdenum steels, and on the rate of their melting, effect of melting point of iron, mild steel, 12-chromium stainless, 20-8 stainless, Monel, copper, 70-30 brass and pure nickel on slope of erosion curve. Results of metallographic examination of structures of checked areas of ferrous and nonferrous alloys are briefly presented. A table gives rough order of erosion of pure platinum, iron, copper, nickel, silver, zinc and aluminum relative to that of pure iron for the slope of erosion-change curve in melting region. Steel alloys fell between iron and silver. It may be concluded that it is necessary to go to other metals than steel and its alloys. Second part of present article gives authors' experimental data aimed at establishing relation of weight eroded to powder type and vent size. SAE X1020 cold-rolled steel vents only were used. The author found that plotting weight eroded vs. weight of charge gave better correlations than plot of weight eroded vs. pressure. Conclusions are that erosion is of two types, a melting type found above a certain min. pressure, and a chemical type found below it. This agrees with heat transfer theory.—INCO.

The Corrosion of Metals—Part IX. Magnesium and Its Alloys (Continued). *Sheet Metal Ind.*, **25,** 541-546 (1948) Mar.

Discusses galvanic corrosion and its relation to design; stress-corrosion; and corrosion-fatigue.—BLR.

The Corrosion of Metals. Part IX. Magnesium and Its Alloy (Concluded). *Sheet Metal Ind.*, **25,** 963-970, 978 (1948) Apr.

Covers: Effect of heat treatment, including annealing temperature; effect of alloying constituents; effects of impurities; resistance to outdoor exposure, to salt solutions and sea water, to nonaqueous solutions, and to leaded gasoline. Information given is based on a review of the literature, some of the experimental curves from the latter being reproduced. 13 ref.—BLR.

Stress-Corrosion of Manganese-Bronze Castings in Submarine Service. Thomas L. Sheehan and Howard E. Dickerman, *J. Amer. Soc. Naval Engr.*, **58,** No. 4, 586-598 (1946); and (abridged) *Engineer*, **183,** No. 4761, 356-357 (1947).

An examination of records of failure of manganese-bronze castings in naval use showed that in each case the casting had been submerged in sea water in use, was of β structure, and had failed through intergranular cracks. The laboratory investigation subsequently carried out was designed to compare the resistance to stress-corrosion in sea water of castings having β and α/β microstructures. Three sets of specimens were prepared, basically of the Navy Dept. 49 B3e type (copper 55-60, lead 0.40 maximum, aluminum 1.50 maximum, manganese 3.50 maximum, iron 0.40-2.00, tin 1.00 maximum, other elements 0.20% maximum each, zinc remainder), with minor variations to produce the required microstructure. The first set was obtained from a β-bronze rocker arm which had failed in service, and the second and third sets from special heats calculated to produce β and α/β microstructures, respectively. Specimens were immersed for given periods under load in sea water, the load being increased in successive steps until failure occurred. Full experimental data are given. Both types failed, but the β type was more susceptible than the α/β type. The max. loads in excess of their yield strength withstood by the β and α/β types, respectively, were 1594 and 8625 lb./in.^{2}; the max. average elongations 1.9 and 8.4%, and the average immersion periods 4.31 and 82.25 days. Failures were intergranular for β bronze, and transcrystalline for α/β bronze.—MA.

Methods of Studying the Stress-Corrosion of Light Alloys. S. E. Pavlov, Lavodskaya Laboratoriya, (U.S.S.R.) **13,** No. 10, 1234-1244 (1947). **Light Metals Res. 9,** No. 3, 76, (1948) Feb. 4.

Methods described in the literature are dealt with, being grouped into those involving bending of the test piece and into those in which the test piece is subjected to a tensile stress. Choice of the corrosive medium and methods of examining corroded specimens are briefly referred to, the latter with some typical photomicrographs.—ALL.

On the Influence of Stress on the Risk of Failure by Stress-Corrosion (of Aluminum Alloys). Kurt Matthaes, *Metallforschung*, **2,** Nos. 7/8 213-225 (1947).

High-strength light-metal alloys such as aluminum-copper-magnesium and aluminum-zinc-magnesium are used in spite of their known sensitiveness to stress-corrosion and the fact that specimens generally give deformation values higher than those possible in practice. Tests show that: 1) in general there is no lower limit below which a material is absolutely resistant to stress-corrosion, although in practice the life at lower stresses is so high that a good degree of safety can be reached under usual corrosion conditions, and notches do not increase the tendency to failure; and 2) stress-corrosion cannot be considered only as an electrochemical solution process, for the magnitude of the stress is just as important as other influences, such as the nature of the corrosive medium and the condition of the material (cold worked, annealed, etc.), and similar cracks and breaking appear in synthetic resins, where no electrochemical solution is possible. Thus, stress-corrosion failure is a genuine failure similar to that by fatigue or corrosion fatigue. Further tests on stress-corrosion failure by other than tensile stress—by torsional or alternating-bend tests—show that failure always occurs as a normal tensile failure in which the rupture planes are always perpendicular to the max. tensile stress. It is concluded that the risk of failure cannot be explained simply by the normal stress hypothesis or any other similar theories such as those of max. extension, energy of change of state, or shear stress, as it depends largely on the degree of plastic deformation. Failure under stress near to the elastic or proof stress can be explained largely by the energy of change of state hypothesis; at higher stresses

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the shear stress hypothesis is more appropriate.—MA.

The Effect of Low-Temperature Annealing in Preventing Grain Growth. Uniform Growth of Crystal Grains. S. Ishida, *Rept. Aeronaut. Res. Inst.,* Tokyo Imp. Univ. (Japan), No. 291, 208-230 (1944); *Chem. Abst.* **42,** No. 4, 1168 (1948) Feb. 20.

It long has been known that heating metals and alloys above their recrystallization temperatures after they have been slightly cold-worked often leads to abnormal grain growth. The aim of this work was to investigate the mechanism of this and its prevention. In slightly cold-worked Super-Duralumin, the grains are finer in size when the metal is subjected to a proper period of intermediate annealing at 300° C. (572° F.) before heating at the quenching temperature. The effect of low-temperature annealing is not due entirely to the precipitation of intermetallic compounds. By intermediate low-temperature annealing following a small amount of cold-working both pure aluminum and highly purified aluminum show at first some decrease in hardness but afterwards at 75-100° C. (167-212° F.), harden again to a degree equal to their cold-worked condition. The hardening after cold-working does not always occur equally throughout the whole area but sometimes is abnormally localized. On annealing, however, the regions of average hardness remain unchanged, while in the abnormally hardened regions, the hardness decreases nearly to the average. It seems that at the same time a slight change in the dimensions of the crystals takes place; this causes natural plastic deformation. In order to produce minute and uniform crystals, the distribution as well as the amount of strain must be uniform. It is necessary to adopt such a process as low-temperature annealing after the working operation for obtaining even strain. The effect of intermediate annealing after the cold-working of pure metals in preventing grain growth is due to the equalization of the strain. In Duralumin, etc., where low temperature annealing is accompanied by the precipitation of some intermetallic compounds, the effect is due to a combination of the two factors precipitation and equalization.—ALL.

The Season Cracking of Aluminum-zinc-magnesium-copper Alloys. S. Ishida and Y. Onishi. *Rept. Aeronaut. Research Inst.,* Tokyo Imp. Univ. (Japan), No. 256, 187-209 (1943). *Chem. Abst.* **42,** No. 4, 1171 (1948) Feb. 20.

Problems relating to the season cracking of the aluminum alloy containing zinc 9%, magnesium 2%, and copper 3% are dealt with. Attempts were made to investigate the relation between season cracking and corrosion with special attention directed to the properties of the crystal boundaries of the alloy. Similar to the tempered aluminum-magnesium alloys, when the alloys of this series are in a condition very susceptible to season cracking, e.g., when tempered for four days at 60° C. (140° F.) after quenching, they are subject to intercrystalline corrosion by dipping in 3% sodium-chloride solution. The quenched and tempered condition of the alloy is not always stabilized at room temperature; sometimes the ageing proceeds with time. This makes the alloy especially sensitive to season cracking. This phenomenon also occurs in a vacuum of about 2 mm. mercury. Thus it seems to be caused not only by atmospheric corrosion but also by the fact that the ageing velocity varies locally and the delayed parts continue to age gradually even at room temperature.—ALL.

On the Stress-Corrosion of Heterogeneous Alloys. Ludwig Graf. *Metallforschung,* **2,** Nos. 7/8, 207-212 (1947).

Although the stress-corrosion properties of heterogeneous alloys follow the same general rules as for homogeneous alloys, additional factors are introduced by the nature and amount of the individual phases present. These phases have two properties which are entirely independent of one another, namely their own sensitivity to stress-corrosion and purely chemical resistance to the corrosive medium. No danger of stress-corrosion exists only when there is a complete chemical resistance to the corrosive medium. The heterogeneity of alloys may be divided into two classes: 1) grain-boundary heterogeneity, where the second phase is only in small amount; it is generally distributed around the grain boundaries; 2) structural heterogeneity, where about equal amounts of two phases are present. With grain-boundary heterogeneity the stress-corrosion properties depend only on the chemical resistance and sensitiveness to stress-corrosion of the minor phase, but with structural heterogeneity the following factors are of importance: a) the relative amounts of the phases, b) the electrochemical p.d. between the phases, one of which may be sensitive and the other

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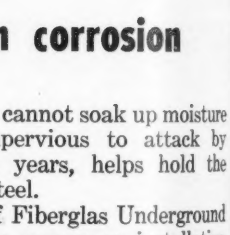

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insensitive to stress-corrosion, and c) the nature of the corrosive medium. On this basis the differing corrosion properties of the aluminum-magnesium alloys compared with the aluminum-magnesium-zinc alloys are explained; the former have an intercrystalline phase, Al_3Mg_2, resistant to stress-corrosion but chemically unstable, whereas the latter have phases Al_2Mg_3, Zn_3 and $MgZn_2$ which are very sensitive to stress-corrosion but very resistant chemically. A similar explanation is given for the properties of α/β brass, gold-silver-copper, and gold-copper-nickel alloys.—MA.

Abrasion, Erosion and Corrosion. C. H. Desch, Paper before Soc. of Chem. Ind., Chem. Eng. Group, London, Jan. 20, 1948, *Chem. & Ind.*, No. 8, 122 (1948) Feb. 21.

Fundamental work of past and present investigators was discussed and linked with practical application. Surface flow, friction between two surfaces, importance of melting point above hardness in polishing, revealing of micro cracks in copper by electrolytic polishing and sulphide etching, erosion problems as exemplified by action of wet steam on turbine blades and cavitation of marine propellers and pump impellers were mentioned. Regret was expressed that so little use of the microscope is made in corrosion investigations. Intergranular corrosion is of great importance in fabricating items of plant and a closer study of conditions of grain boundaries is required as also the specific action of reagents on cold-worked materials. The complex steels developed for the gas turbine were finally discussed.—INCO.

SURFACE PREPARATION

Electrochemical Cleaning of a Large Steel Casting: An Experiment. John A. Wettergreen, *American Foundryman*, **13,** 120-124, (1948) Apr.

Gives results of a successful experiment conducted to determine the possibilities of removing fused sand and iron oxides from the interior of a large cast-steel turbine shell by use of an electrolytic molten-caustic bath.—BLR.

Molten Salt Bath Descaling Provides Greater Metal Savings. *Steel*, **122,** 90 (1948) Mar. 29.

Tells how the problem of scale removal from hot-rolled clad plate and sheet, including stainless, nickel, and Monel, was solved recently at Lukens Steel Co., Coatesville, Pa.—BLR.

Preparation of Wrought Aluminum for Painting. R. H. Prislin, *Enamelist*, **25,** 7-9, 61+ (1948) Apr.

Gives classification charts of aluminum-alloy sheet and plate. Discusses physical treatments, solvent precleaning and chemical cleaning. (To be continued.)—BLR.

Precision Tumbling. R. M. Lord, Norton Co., *Steel*, **121,** No. 24, 93-94, 124 (1947) Dec. 15.

The precision tumbling process for metal parts is described and its advantages and uses enumerated. Abrasive tumbling produces uniformity in operations such as breaking edges, producing radii to blueprint specifications, finishing operations, and has brought about ultra-fine finishes measureable in microinches. It controls dimensional loss, increases wear-resistance, eliminates rework and human element. It also increases life of cutting tools and dies on parts which have to be machined after the removal of burrs. Heavier burrs can be left on work because they can be easily removed by tumbling process. For operations where fast cutting of untumbled abrasive is not desired, this material is pretumbled at plant to provide a product ready for use. When using the finer sizes for tumbling or retumbling parts of a relatively soft material like brass or a die cast metal, it is desirable to run barrel for about an hour with abrasive and water only, before adding work. General procedure and a new abrasive, "Alundum tumbling abrasive," manufactured by the Norton Co., are described. To prevent subsequent rusting or corrosion by slushing; after wash operation, parts are tumbled with a special oil preparation, which is water repellent. Complete short term protection is thus obtained for storage of parts. A solvent film of less than 0.0002-in. thickness is formed. Examples of tumbling jobs are given, including obtaining of a bright finish on hardware, stampings and machined parts of bronze, brass and other nonferrous metals. Suggested procedures are given for deburring of gears also.—INCO.

Sodium Hydride in Descaling Stainless Steel Sheets. M. H. Lebowitz, *Steel*, **122,** 107+ (1948) Apr. 5.

Tells how surface quality is improved and finishing operations speeded during final processing by use of a molten so-

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dium hydroxide bath, impregnated with sodium hydride, for above operation at Wood Works, Carnegie-Illinois Steel Corp., McKeesport, Pa.—BLR.

Secondary Reactions in Phosphating Baths. E. Jaudon. *Comptes Rendus* (Paris), **218,** 915-917 (1944).

Speeding up of phosphating reaction by small addition of copper salts, effect of addition of such ions as chlorate or nitrate, influence of pH of the bath upon the solution of iron from wall of treating tank, presumable mechanism of oxidation of iron, and bubbling of air through the phosphating bath are discussed.—INCO.

Phosphate Treatments for Zinc Surfaces. E. E. Halls, *Metallurgia,* **37,** No. 222, 299-305 (1948) April.

Report of tests of various phosphate treatments applied to zinc alloy die-castings and to hot-dip galvanized, electrogalvanized and zinc-sprayed steel parts. Stoving and air-drying lacquers were then applied and corrosion resistance and adhesion tested. Test periods covered periods up to one year.

Conditions for Passivation of Stainless Steels and its Practical Application. L. Guitton, *Metal Treatment,* **15,** No. 53, 3-13 (1948) Spring.

Passivation by chemical and anodic treatments. Author discusses sensitization, and shows that laboratory samples and even shaped and welded parts may be perfectly resistant to normally corrosive media when passivated beforehand. —BNF.

Passivating Treatments May Improve Cadmium-Plate Coatings. Allen G. Gray, *Prod. Fin.,* **11,** No. 10, 60-62 (1947).

A brief note giving details of a suitable solution for passivating cadmium coatings.—MA.

Acid Dichromate Treatment for Magnesium Alloys. George Black, *Prod. Fin.,* **11,** No. 10, 42-44, 46 (1947).

Details of solution composition, operating conditions, and preparation of the work are given.—MA.

TESTING

Report on the Use of Elektron in Synthetic-Resin Mouldings. (Corrosion Tests.) C. J. Bushrod, *Magnesium Rev. and Abs.,* **7,** No. 1, 18-22 (1947).

An account of tests to ascertain whether magnesium alloy (Elektron AZ91 and AZM) inserts are suitable for use with plastics of the phenol-formaldehyde and cellulose acetate types. Cracking and corrosion tests showed that the magnesium alloy inserts behaved well; corrosion of the inserts was not rapid enough to be important, though with the acetate resin better results are to be expected after lacquering the insert.—MA.

Irreversible Electrode Potentials of Metals and Their Solid Solutions. Part I. Irreversible Electrode Potentials of Metals. Part II. Electrode Potentials of Solid Solutions. G. V. Akimov and G. B. Clark, *Trans. of the Faraday Soc.* **43,** 679-697 (1947) Nov.-Dec.

A method of measurement of electrode potential of metals and alloys during the rubbing of the surface of a test-piece under a solution was developed. The comparison of the potentials obtained, without rubbing and while rubbing, permits conclusions to be made about the tendency of a metal to form a protective film. The electrode potentials of 22 metals — beryllium, magnesium, aluminum, silicon, Nb, chromium, molybdenum, manganese, iron, cobalt, nickel, copper, silver, gold, zinc, cadmium, mercury, thallium, tin, lead, antimony, bismuth— were measured in 0.1 N. HCL, 0.1 N. HNO_3, 01. N. NaOH and 3% sodium chloride solutions. From the results for pure metals it is concluded that: (a) the greatest tendency to form a protective film is observed in metals belonging to group A (beryllium, magnesium, aluminum, silicon, Nb, chromium, molybdenum, manganese), less in metals of the transition group (iron, cobalt, nickel), and least in metals of iodine-boron-group (copper, silver, gold). The metals of other boron groups (zinc, cadmium, mercury, tin, lead, sulfur, bismuth) show little tendency; (b) the behavior of metals of the same group of Mendeleeff's table as regards alteration in electrode potential caused by rubbing of the surface under solution (mechanical activation) is similar, being independent of the electrode potential value. Some suggestions are made about the nature of irreversible potentials of pure metals and solid solutions. The electrode potentials of the following 23 systems: Aluminum with copper, zinc, magnesium, lithium, silicon; zinc with aluminum, copper, silver, gold; magnesium with aluminum, zinc, cadmium, thallium, tin, lead; copper with aluminum, zinc, nickel, manganese, silver, beryllium, cadmium, tin, were measured. The measurements were performed in 0.1 N. HCL, 0.1 N. HNO_3, 0.1 N. NaOH and 3% NaCl solutions by the usual and by newly developed methods. The results of the electrode potentials of solid solutions have been classified into groups according to the relationship between the potential of a solid solution and its composition. Beside the normal relationship between the electrode potential and the composition of the solid solution (decrease of the potential with introduction of the anodic component and increase with introduction of the cathodic component), both anomalous cases occur, namely, potential drop with the addition of the cathodic component and increase of potential with the addition of the anodic component. The anomalous case cannot be explained solely in terms of the protective film, since it was also observed when the metal surface was rubbed under the solution, i.e., when the role of a film was minimized. There is no correspondence between the potential of the component and its effect on the potential of the solid solution. The typical group—relating potential and composition—to which a given system of alloys belongs is defined principally by the nature of a) the components and their interaction, b) the solution and c) the protective film. 25 references.—ALL.

Chemical and Thermochemical Principles of Corrosion of Metals in Aqueous Solutions, Exemplified by the Case of Zinc. W. Feitkneckt. *Metaux & Corrosion,* **22,** Nos. 267/268, 192-203 (1947) Nov./Dec.

Chemistry and morphology (X-ray studies) of hydroxides, chlorides and hydroxychlorides of zinc; stability of the

various forms of these compounds. Corrosion of zinc in sodium chloride and zinc chloride solutions; effect of zinc chloride content on type of corrosion; interpretation of results in terms of electrochemical theory and of nature of corrosion product formed. See also German Thesis by R. Petermann, "Chemistry and Morphology of Surface Layers in Corrosion Tests with Zinc"; and the paper of same title by W. Feitknecht and R. Petermann, *Korrosion u. Metallschutz.* 15 References.

Optical Phenomena in Metallic Foils Reduced in Thickness by Chemical Attack. W. F. Burgers and J. Wejdmena, *Rev. Univ. Mines,* **90,** 126-128 (1947). *Chem. Abst.,* 41, 6452 (1947) Oct. 20.

Experiments on 50:50 nickel-iron alloy, 60 mu thick, treated with a solution of 1 vol. nitric acid (Sp. Gr. 1.4) and 2 vols. hydrochloric acid (Sp. Gr. 1.19) applied in drops. After several applications, foil became porous and transparent. Chemical attack follows crystallographic texture of the material. Pores formed are rectangular, and in them a cross-shaped figure appears, apparently owing to an interference phenomenon. The arms of the cross form an angle of 45° with the direction of rolling.—INCO.

On the Influence of Mercury on the Tensile (and Corrosion) Properties of Magnesium - Manganese Alloys. Walter Bulian, *Metallforschung,* **2,** No. 5, 158-160 (1947).

A study was made of the microstructure, tensile, and corrosive properties of wires and sheets of magnesium-manganese alloys containing manganese 1.87% and mercury 0-1.8%. The mercury was added in the form of a magnesium-mercury master alloy containing 11% of mercury, and there was no loss of mercury by burning-off or vaporization during the final melting. The microstructure of the alloy containing 0.38% mercury shows the typical segregation of manganese, with mercury in the form of Mg_3H_g as a fine, discontinuous network round the grain boundaries. The mercury additions cause a noticeable decrease in coarse crystal formation on heat-treatment. With 1% mercury the 0.2% proof stress is higher in the case of sheets but lower in the case of wires, than with the straight magnesium-manganese alloy. Mercury below 0.5% has little effect on the tensile properties; the alloy with 1.8% mercury has a 0.2% proof stress of 20.1 kg./mn.^{2} compared with 17.5 kg./mn.^{2} for the magnesium-manganese alloy, although the tensile strengths and elongations are equal. Warm ageing has practically the same effect as with magnesium-manganese alloys. The corrosion properties of the alloys with mercury additions are generally at least as good as, and in sodium chloride solutions somewhat better than, those of the alloy with no mercury. Large cracks appear on welding the ternary alloys due to burning-off of the mercury.—MA.

Behavior of Experimental Zinc-Steel Couples Underground. Irving A. Denison and Melvin Romanoff, *J. of Res. of the Nat. Bur. of Standards,* **40,** 301-313 (1948) Apr.

Describes and illustrates an investigation on the behavior of zinc anodes for the protection of iron and steel cathodically in eight diverse soil environments. The experiment unit consisted of a small steel ring to which was connected from 1 to 3 zinc cylinders to provide different area ratios of zinc to steel. Corrosion of steel cathodes was prevented over the test periods of from approximately three to six years except in one poorly conducting soil and in a very alkaline soil. 13 ref.—BLR.

Corrosion Tests of Heater-Tube Materials for Acid Concentration Service. H. F. Brown. *Oil and Gas J.,* **46,** 134-137, 149 (1948) Apr. 29.

Describes and illustrates results of tests on a variety of materials in a laboratory concentrator for H_2SO_4. Materials evaluated were: cast 12-14% silicon iron; silicon-nickel alloy; iron-molybdenum-nickel alloy; glass-coated carbon steel; silver and silver-coated steel; and tantalum. No completely satisfactory materials were found.—BLR.

UNDERGROUND

Interstate Lays First Experimental Section of Welded Aluminum Pipe Line. Paul Reed, *Oil and Gas J.,* **46,** 141-143 (1948) Apr. 29.

Described and illustrated. Purpose is to test the ability of aluminum pipe to resist internal corrosion by sour crude and external corrosion by corrosive soils, and also determine economic possibilities of aluminum pipe for the petroleum industry. Describes inert-gas arc welding for the job.—BLR.

The Corrosion of Mains and Services. T. W. Hughes, *National Gas Bull.* (Australia), **11,** 23-29 (1947) Sept.-Oct. Gas *Abstr.* **4,** No. 2, 30 (1948) Feb.

The nature of corrosion found in pipe

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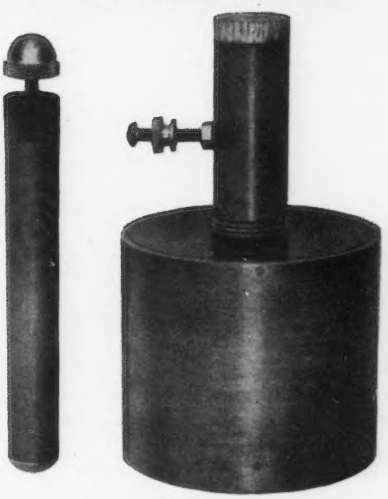

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lines buried in the soil, the environments which influence it both externally and internally, the materials usually used in pipe lines and their relative resistance to corrosion, and a method of combating it are reviewed briefly. No more information in abstract.

WATER

Bronze and Sea-Water Corrosion. *Tin and Its Uses,* No. 19, 4 (1948) Mar.

Following incorrect presentation of illustration in previous issue, figures are shown of the nature of the attack undergone by brass, aluminum-brass, 70-30 cupro-nickel, tin-bronzes (10, 12, and 14% tin) with emphasis on the resistance exhibited by the tin-containing materials. —INCO.

Sea-Water Corrosion. D. M. Smith, *Aeroplane,* **73,** 265 (1947) Sept. 5.

Correction and amplification by author of remarks on the Metrovick Beryl engines in the new Saunders-Roe flying-boat fighter which appeared in Aeroplane, Aug. 8, pp. 148-149.—INCO.

Bureau of Mines Studies Water Treating Plants. *Producers Mo.* **12,** No. 6, 21 (1948) Apr.

A study of water treating plants used in water-flooding operations is being made by the Bureau of Mines Bartlesville Station. Six plants in Kansas and north Texas have been studied to date. In the corrosion test, a 2-inch diameter disc of copper-bearing tank steel is suspended for 72 hours in a half-gallon jar through which the water is passed at a rate of 5 ml./min. The corrosion products are observed, and the loss in weight due to corrosion is determined. This test and other chemical and physical tests are made simultaneously at 4 to 8 points in each plant, and the results are correlated to show the changes taking place in the water in each step in handling. Photographs of the mobile laboratory truck are included.

Corrosion Prevention by Controlled Calcium Carbonate Scale. S. T. Powell, H. E. Bacon and E. L. Knoedler, *Ind. Eng. Chem.,* **40,** 453-7 (1948) Mar.

New data are presented to bring up to date a previous discussion of the use of controlled calcium carbonate scale for corrosion prevention in cooling tower systems serving steel equipment. The original data for the pH temperature curves are recalculated, using more recent values for the ionization constants of carbonic acid. Illustrative problems are given. 10 references.

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Salt Water Corrosion of Ships. R. A. Pomfret and L. M. Mosher, *Corrosion*, **4,** 227-243 (1948) May.

Reviews fundamental principles which are applied in modern shipbuilding practice to minimize corrosion damage, and gives examples of the consequences when these precautions are not observed.—BLR.

Staining of Glass Containers in Contact with Iron. G. C. Marboe & W. A. Weyl, *J. Amer. Ceramic Soc.*, **30,** 320-322 (1947) Oct.

A wet glass surface brought in contact with metallic iron acquires a brown stain which cannot be removed easily. It can be prevented by reagents which 1) prohibit the corrosion of the iron, 2) block the active centers of the silica gel, and 3) produce anionic iron complexes. —INCO.

Fundamentals of Feedwater Treatment. E. W. Feller, *Power*, **91,** No. 12, 63-98 (1947) Dec.

Objectives, various feedwater treatment processes, water chemistry, control tests are presented. Scale formation, corrosion, carry-over, caustic embrittlement, are briefly discussed. Alkalinity, hardness, sulphites, and chlorides of typical raw waters, flow diagrams and typical equipment for water softening, molecular and equivalent weights of many elements and compounds are conveniently presented in graphic form.—INCO.

Deaeration of Boiler Feedwater for Atomic Power Plants. S. D. Distelhorst, Cochrans Corp., *Power Plant Eng.*, **53,** No. 12 107-108 (1947) Dec.

The simplest solution to the industrial utilization of atomic energy is some sort of a steam generating boiler. Generation of steam probably will take place in a liquid to liquid heat exchanger rather than from the heat of a gas. Degasification of boiler feedwater for high-temperature piles operating for purpose of steam generation is briefly discussed. To protect the heat exchange equipment from corrosion even in low-temperature operation, removal of corrosive non-condensable gases is necessary.—INCO.

Intercrystalline and Other Types of Corrosion of Steam Boilers. *Am. Railway Engineering Assoc. Bull.*, **49,** 66-67 (1947) Nov. *Metals Rev.* **21,** No. 1, 38 (1948) Jan.

Committee report indicates that all-welded construction should result in a satisfactory boiler, free of seams which facilitate concentrations of dissolved solids contributing to intercrystalline corrosion.—INCO.

A Zinc-Base High Alloy of High Aluminum Content. III.—Water-Vapour Corrosion of Forging Alloys. Erich Gebhardt, *Metallforschung*, **2,** Nos. 7/8, 225-230 (1947).

A study was made of the water-vapor corrosion, at 95° C., of a zinc-base alloy containing aluminum 32% and copper 3%, in the form of forged rods. Alloys made from technically pure metals had corrosion films 0.05 mm. thick after 5 days' testing. Additions of lead, cadmium, or zinc increased the susceptibility to corrosion, but the deleterious effects of these metals could be lessened

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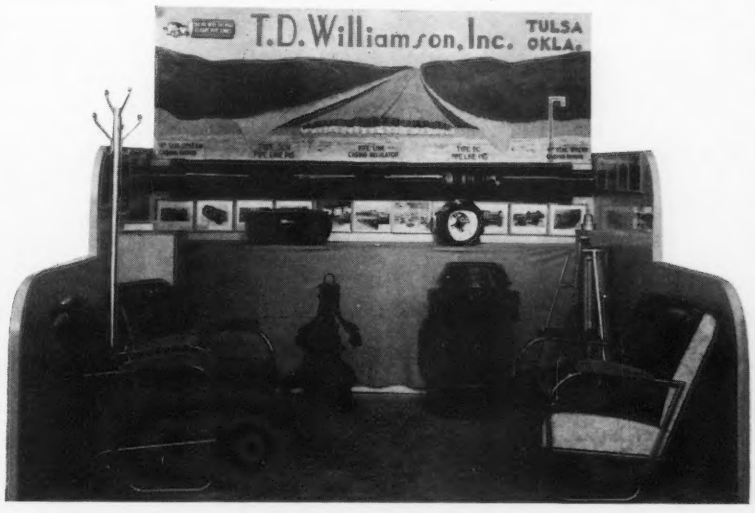

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by addition of magnesium; iron, silicon, manganese, or nickel had no deleterious effects on the corrosion properties. Commercial alloys, prepared from secondary metals, showed much greater rates of corrosion; after 5 days the corrosion films were 0.35-0.5 mm. thick. Of all metals, the presence of lead had the worst effect on the corrosion-resisting properties.—MA.

The Corrosion of High Purity Zinc and Its Alloys. (In German.) L. W. Haase, *Metalloberflache*, **1**, 73-77 (1947) Apr.

Gives results of investigation of the electrochemical behavior of pure zinc and its alloys for use in water installations. Galvanized coatings for protecting steel are also discussed. Concludes that zinc alloys cannot be substituted for brasses and bronzes in handling water.—BLR.

Sulphate-Reducing Bacteria in Industrial Waters: Proposed Tentative Method of Test. American Society for Testing Materials, *A.S.T.M. Preprint* No. 74, 19-28 (1948).

Includes an appendix on proposed method for identification of types of micro-organisms in industrial waters.—BNF.

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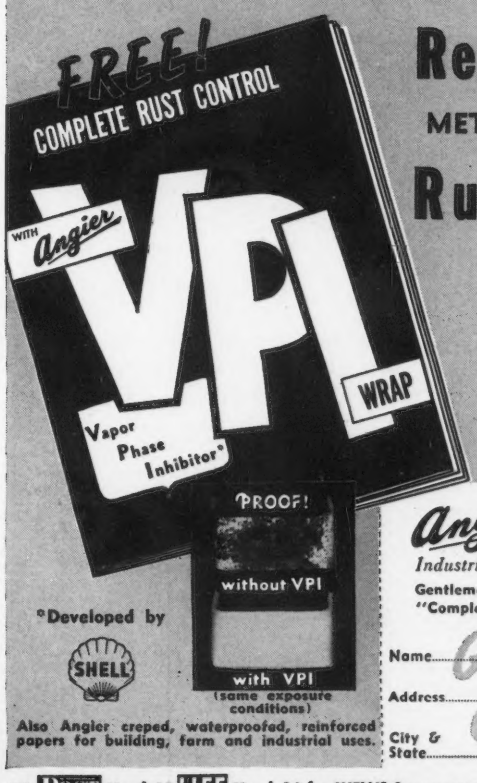

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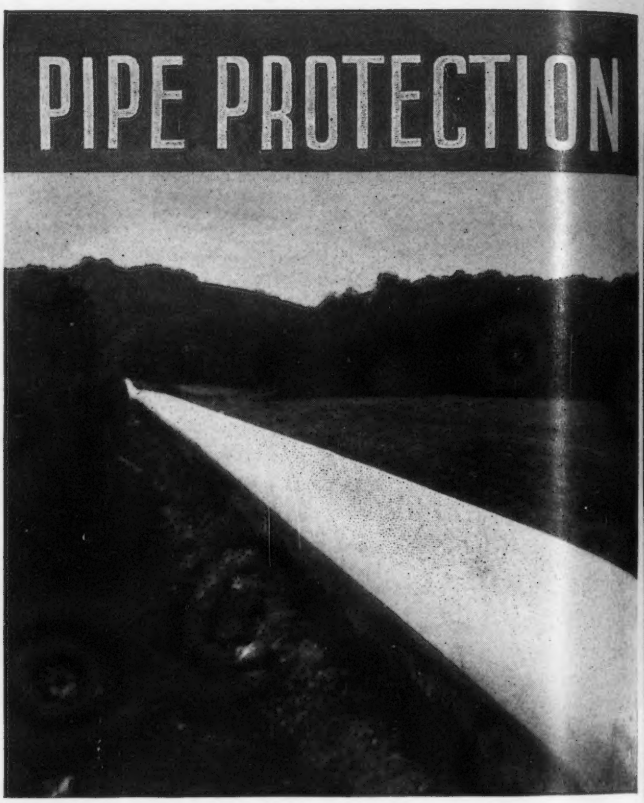

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